LUCAS TANK MISSION

DECEMBER 1st, 1943.

SECRET

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The attached copy of report by Mr. Oliver Lucas on his mission to U.S. and Canada is forwarded for information and consideration at the 37th Meeting.

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MOST SECRET

THE RT. HON. SIR ANDREW RAE DUNCAN, G.B.E., M.P.,

Minister of Supply

Sir,

In accordance with your instructions, the undersigned members of the Lucas Tank Mission left for America on October 9th, 1943.

I beg to submit herewith our unanimous report dealing with the terms of reference and certain other matters of major interest.

I have the honour to be, Sir,

Your obedient servant,

(SIGNED) OLIVER LUCAS.

MEMBERS OF THE MISSION

Oliver Lucas ..... Chairman.
Brig. W.F. Morrogh, D.S.O.
Harold Drew.
Colonel H. de J. Keays.
H.I.F. Evernden.
T.A. Swinden ..... Secretary.

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INTRODUCTION

The Mission arrived in Washington on October 11th and on the following morning was received by Sir Walter Venning, Sir Leonard Browett, General Gatehouse, and Lt. Col. McGoun.

The British Supply Mission had worked out a preliminary draft of an itinerary for us. This was discussed in some detail and modified particularly in order to provide for an early visit to Canada. A general discussion on tank development took place.

In the afternoon, accompanied by General Gatehouse, we paid our first visit to General Barnes of the U. S. Ordnance at the vast Pentagon Building just outside Washington.

We should like to record that throughout our visit we have been received with the utmost courtesy by all members of U.S. Ordnance and by the Tank Industry. They have taken great pains to show us everything of interest and they have spent much time with us in discussions. Without exception they have talked frankly and taken us into their confidence. On no occasion were we made to feel that our presence was a nuisance to them although it is obvious that, at least at times, this must have been the case. Being conscious of the fact that our hosts were all busy men with great responsibilities on their shoulders we were very appreciative of their patience.

In the report which follows, we have included much information which has already appeared in B.S.M. Situation Reports. We have not in every case acknowledged such references. We have also repeated certain information contained in cables dispatched by us subsequent to our arrival.

It is hoped that the form which we have chosen for our report will be found convenient. We have endeavoured to find a layout which will suit both those who are interested in the broad picture and also those who are interested in matters of greater detail. This has necessarily involved a certain amount of repetition.

The report is divided as follows:-

1. Introduction.

2. General Impressions.

3. Discussions of the various matters comprising our terms of reference, item by item, and summary of recommendations arising therefrom.

4. Visits to Canada.

5. Appendices dealing with specific items.

GENERAL IMPRESSIONS

When thinking about U.S. armament policy, it may be useful to bear in mind the state of public opinion. The impressions of this which follow are our own and they are formed from the large number of contacts which we have made with all manner of people.

Opinion appears almost unanimous with regard to the imminent collapse of Germany. The war in Europe is considered to be in its final stages. It is expected to be over at the very latest by September of next year. (The accounts of destruction in the Reich which appear in the U.S. Press certainly do not underestimate the havoc.) It is true that many responsible people are well aware of the dangers of counting prematurely on such an eventuality and they will no doubt use their influence to counter policies based on rash speculation.

Although the manufacture and distribution of non-essential consumer goods has by no means been restricted to the extent that it has in the U.K., at the same time an incredible flow of all kinds of warlike material pours from the immense defence plants. We have, however, encountered much talk on the subject of cutting down on certain items of equipment and even on closing down certain plants. The following passage is quoted from a Washington despatch printed in the Detroit Free Press on November 29th.

> "Within a few months the War Department will begin the cancellation of many contracts held by the motor firms for equipment now being used in the European theatre and which is not needed for the Pacific War fare."

It is not surprising in an atmosphere such as this, to find traces of a certain hesitancy in some quarters with regard to those long term projects, the application of which is limited to the European theatre.

There is no such easy optimism with regard to the future in the Pacific. The Japanese are expected to resist stubbornly and effectively to the bitter end.

U.S. FAITH IN MEDIUM TANK M4.

Everywhere we went, we were impressed by the faith which the U.S. have in their Medium M4 Tank, now shortly to be equipped with the 76 mm high velocity gun for certain roles.

They have achieved a high degree of standardization and interchangeability. This will be further improved as the number of engine types in use is reduced. They have a great number of these machines in service and elaborate provision for their manufacture, maintenance, and repair. The machine itself has been developed to an enviable standard of reliability.

It is not surprising therefore, to find that they are very reluctant to abandon this machine at least until they have convinced themselves of the superiority of its successors.

As a consequence, there are no signs of preparations for the large scale production of the various new machines now in prototype form or on order in relatively small numbers.

The U.S. Army Staff do not seem to be very impressed with the urgency of the need for developing very heavily armoured machines for the assault role.

It is clear that the U.S. forces will have no Medium Tank other than the M4 available for fighting during the year 1944, except possibly in negligible numbers. They will certainly have no heavy tanks.

ARMOUR THICKNESS AND DISPOSITION

U.S. Ordnance seem to take a very realistic view of the problem of armour thickness and its disposition. Like every one else they hold that, other things being equal, the more armour which can be carried the more effective will the tank be. They are very conscious, however, of the price that has to be paid for an increase of armour. For a given degree of skill in design, an increase in armour thickness must be paid for by accepting sacrifices in other features such as

1. Simplicity and ease of maintenance.
2. Speed and manoeuverability.
3. Overall size and weight with its effect on target area, bridge requirements and road or rail transportation.
4. Utilization of labour and materials in manufacture.

They are also well aware of the fact that the design and development of larger and heavier machines sets the designers a problem which becomes increasingly difficult with every advance.

With regard to the disposition of armour, General Barnes expressed the view of U.S. Ordnance very clearly. The designer, he said, would provide the maximum weight of armour on the sides, which the tank was capable of carrying. He would then settle the thickness of the frontal armour largely by consideration of the centre of gravity of the machine. Since it was invariably necessary to bring this forward, the designer would choose to add armour to the extreme front of the hull. This would result in frontal armour far in excess of side armour and even somewhat in excess of that on the turret front. From a military point of view, it is fairly obvious that there is a case for more armour on the turret front than on the hull front, since the former is usually much more accessible to the enemy. (General Christmas, on a later occasion, told us that, as a result of battle experiences, serious consideration is being given to the possibility of increasing the turret armour.) Put even more simply, the military must regard excess armour on the front of the hull as a useful, if fortuitious, local reinforcement, but they must not expect a similar standard throughout the machine nor must they regard this local armour as establishing a quotable armour basis.

General Christmas of the Tank Automotive Centre is thinking ahead on a most interesting line. He views with some alarm the tendency to accept larger and larger machines for the sake of enclosing very powerful guns in very heavy armour. He calls attention to the duties of the pilot of a fighter aircraft. The pilot is driver, navigator, gunner and commander. Whilst he does not visualize a one-man tank he is looking for a saving in the size of the tank by mechanization and consequent elimination of certain of the crew. He talks of automatic loading and even of the possibility of eliminating the driver, by taking advantage of the possibilities of remote control offered by electric drive, and transferring the driver's duties to the tank commander. He reasons that the fewer the men who have to be enclosed within heavy armour, the less will be the space required, and therefore, the greater the protection which can be provided.

This line of thought opens up the possibility of a substantial increase in armour obtainable without the penalties associated with great size and weight. It was on reasoning similar to this that the Valiant was conceived.

General Christmas is himself a strong advocate for a heavily armoured tank. He points out, however, that the U.S. Army Staff have stated definitely that there is no requirement for any kind of heavily armoured tank.

With regard to the armouring of gun motor carriages, General Barnes told us that in his personal opinion no machine should carry armour heavier than was necessary to give protection against splinters. This policy appears to have been adopted on the latest machine (T70) which has been designed as a self-propelled mounting and is not an adapted tank.

TRANSMISSIONS AND STEERING

The current range of U.S. Medium Tanks (M4) appears likely to continue indefinitely with the present Synchromesh Gearbox and Cletrac Steering System. The gearbox seems to have been considerably improved in detail and gear changing is now very much easier than it was on earlier examples.

In the same way the combination of a fluid flywheel, Hydramatic Gearbox and Cletrac Steering has maintained its reputation and will continue in use on the present light tank. It is also to be retained on the new Light Tank (T24) scheduled for production early next year.

The Merritt Brown system, with which the Americans have now had some experience on Cromwell and Centaur Tanks at Aberdeen and elsewhere, does not seem to appeal to them. They do not like the inability to make sharp turns in the higher ratios. Apparently, drivers used to Cletrac Steering Systems object to changing down on approaching sharp corners. In addition, it is felt that the training necessary to teach gear changing is excessive, particularly in view of the decreasing mechanical aptitude displayed by recently enlisted men. The designs for all future Medium and Heavy Tanks are based on the use of infinitely variable transmissions, requiring little or no skill from the driver. All that is required is a little common sense and a little restraint.

There are two approaches to this problem, the one Electrical and the other Hydraulic. The former approach leads to a considerable increase in weight but gives the simplest control. Steering, braking and reversing are all effected electrically by means of a pair of small levers which are very light to operate. The latter (i.e. Hydraulic) approach also simplifies driving but in this case the Cletrac Steering System is retained. In addition, three gear ranges have been provided. The appropriate range can be

selected before starting or can be changed on the move without shock by simply moving a small lever into another notch. It is important to understand that this system includes a torque convertor as distinct from a fluid flywheel. The torque convertor provides a continuous and automatic variation in ratio whichever of the three ranges is in use.

Advantage is being taken of the simplified control in both cases to provide dual control for driver and front gunner.

Both systems entirely eliminate the clutch, remove the hazard of stalled engines, and enable the driver to concentrate on the terrain. They also both permit high speeds in reverse, and they provide continuous traction, a useful advantage in heavy going. U.S. Ordnance and the Industry seem entirely convinced that better engine life is obtained with these systems owing to the cushioning effect obtained.

The Electric Transmission has been developed by the General Electric Corporation and is sponsored by the Chrysler Corporation. The Hydraulic Transmission has been developed by Detroit Transmission and the Spicer Manufacturing Company, and is sponsored by General Motors Corporation. Further particulars will be found in Appendix 1.

There is no doubt that both U.S. Ordnance and the Military Authorities are entirely convinced of the advantages of these two systems. This is very evident from the fact that complete reliance is being placed on the successful development of these transmissions for all future designs of Medium and Heavy Tanks. There is no sign of hedging, such as the development of more conventional systems for these tanks on the side. In our opinion, this situation is not without its dangers. Although we see no reason why these transmissions should not prove entirely satisfactory, we feel that the time involved is hardly predictable. Any serious difficulties which might arise would necessarily leave the U.S. with nothing but the current Medium Tanks until solutions can be found. In general, however, we do not believe that the U.S. Authorities are accepting anything more than a warrantable war risk, bearing in mind the satisfaction expressed with the current M4.

SPEED

We were struck by the relatively high speeds for which the U.S. are striving on their new Medium and Heavy Tanks and also on their heavy Gun Motor Carriages. The speeds quoted below for those machines which are under development must be accepted with reserve as experience may well result in revised ideas.

Medium Tank	M4A1	Wright Engine	24 M.P.H.
Medium Tank	M4A2	G.M. Diesel Engine	29 M.P.H.
Medium Tank	M4A3	Ford Engine	28 M.P.H.
Medium Tank	M4A4	Chrysler Engine	23 M.P.H.
Medium Tank	T.23	Ford Engine	35 M.P.H.
Medium Tank	T.25	Ford Engine	32 M.P.H.
Heavy Tank	T.26	Ford Engine	27 M.P.H.
Gun Motor Carriage	T.70	Continental Engine	50 M.P.H.

A speed of 27 M.P.H. for the T.26, a machine which is likely to weigh at least 90,000 lbs. or say 40 long tons, would appear to us to be ambitious. A speed of 50 M.P.H. on a Gun Motor Carriage (T.70) running on steel tracks and equipped with Cletrac Steering seems definitely hazardous, at least for running on normal roads. We cannot imagine that such a speed is often likely to be required in operational use.

TESTING AND TRAINING FACILITIES

We were much impressed by the extensive and well equipped testing and training establishments maintained by the U.S. Military Authorities, the U.S. Ordnance and the Tank Industry. Visits were paid to the more important of these establishments.

Camp Young in California is the headquarters of the Desert Training Centre and also of the Desert Warfare Board. The latter establishment is responsible for the service trials of tanks, gun motor carriages, armoured cars, wheeled transport and all other military vehicles under desert conditions. The training centre is the largest in the United States and probably the largest in the world. Since it covers an area greater than that of the whole of England, it is clear that it offers opportunities for training on a scale with which we cannot compete in the U.K. In this same area at Camp Seely, the U.S. Ordnance maintain an extensive proving ground where they carry out development work on a large scale.

Aberdeen proving ground in Maryland is, however, the main testing establishment of U.S. Ordnance. It lies about 70 miles from Ordnance Headquarters in the Pentagon Building at Washington. This establishment deals with the testing of all kinds of military equipment including artillery. Tanks and armoured cars are tested under a great variety of conditions and there are a number of proving grounds provided for this purpose.

Fort Knox in Kentucky is, in the main, a training centre for the armoured forces. A very large area is available for this purpose and training is carried out under realistic conditions with live ammunition. We were very favourably impressed by the quality of training offered and by the enthusiasm with which it is absorbed. This establishment is also the headquarters of the Armoured Board, a body which is the final authority for the acceptance of fighting equipment by the Military Authorities.

In addition to the above establishments, visits were also paid to the General Motors Proving Ground at Milford, the Chrysler Proving Ground at Utica, a number of smaller experimental and production testing grounds maintained by manufacturers and the Canadian Proving Ground near Ottawa. There is no doubt that test and development facilities in the U.S. are very highly developed. The test conditions imposed appear to us to be severe but at the same time we saw no signs of the reckless abuse of vehicles which can be such a danger to the progress of design and development.

If the U.S. use these facilities to the best advantage there should be little risk of unbattleworthy machines finding their way into the services. In theory, at least, the manufacturer satisfies himself on his own proving ground, U.S. Ordnance satisfy themselves that they have a machine fit for production, and finally, the Armoured Board satisfy themselves that the machine meets the requirements of the army. In practice, of course, there is some overlapping of function and considerable overlapping in the timing of this work. Development and testing proceed simultaneously in the later stages at the manufacturers proving ground, at Aberdeen and at Fort Knox. Much time can, of course, be saved by such overlapping if it is applied intelligently.

Certain machines such as the T.9 Light Airborne Tank and the T.17 Armoured Car have been released for production without being subjected to this procedure. This was at the time thought to be justified by the extreme urgency of the requirement. As was only to be expected, this resulted in machines reaching the services with many serious defects. It should, of course, be obvious that such unfortunate incidents are in no way a reflection on the excellent testing facilities available in the U.S.

RIVALRY IN THE INDUSTRY AND RELATIONS WITH ORDNANCE

It is evident that there is a spirit of intense, but friendly, rivalry between the leaders in the Tank Industry. There is no doubt that this competitive spirit encourages enterprise and spurs on development. A good example of this can be observed in connection with transmission developments. General Motors Corporation are applying an intensive effort to the perfection of Hydraulic types and the Chrysler Corporation are devoting an equal effort to the application of the General Electric system. Both of these developments are receiving the utmost encouragement from the Tank Automotive Centre and from U.S. Ordnance as a whole.

In this connection, the excellent relations existing between the industry and U.S. Ordnance are very apparent. The various project officers of the Tank Automotive Centre, who are chiefly responsible for the immediate contact with the industry, struck us as an extremely competent and sympathetic group of men. The Tank industry is largely concentrated in the Detroit district and the fact that the Tank Automotive Centre is itself located in Detroit is a factor of major importance. The atmosphere of mutual confidence and understanding which exists is most impressive.

There does not seem to be a great deal of direct contact between the user and the industry in Detroit and it is at least possible that this insulates the manufacturer from a great deal of confused thought. On the other hand, the manufacturers maintain technical representatives in the field on a large scale. These engineers are often in uniform and go right up to the forward areas. The first hand information which thus gets back to the manufacturer from their own men is, of course, invaluable.

In the course of a conversation with General Christmas, he was kind enough to congratulate us on the excellence of the B.S.M. personnel with whom he is in continual touch. He paid tribute to the invaluable assistance and advice which he receives from them.

ENGINE SITUATION

In view of the U.K. interest in T.23, T.25 & T.26 machines, it is important to remember that they are all of a low silhouette design. The only engine in production in America to-day which will fit into the engine compartment and supply sufficient power for these vehicles is the Ford 8 cylinder.

This unit has now emerged from the teething troubles universally experienced with a new engine, and opinion was expressed by all parties, in our view with ample justification, that it is now a first class tank engine.

The low silhouette requirement has undoubtedly urged forward development work at high pressure and produced a satisfactory engine in a reasonably short space of time.

Fords are at the present time producing engines in their Lincoln plant at the rate of about 600 per month. Unless there is a substantial reduction in the U.S. tank building programme - a possibility hinted at by General Barnes - there would appear to be little chance of obtaining Ford engines for the U.K. in time or in the numbers to be of value on Centaur.

If, as appears likely, Continental Motors undertake manufacture, they will produce a further 200 engines per month, and some of these could probably be supplied to U.K. if the requirements were stated in the immediate future, Even so, it is very improbable that they would be available in England in less than twelve months from now.

This situation was explained by cable. (Lucmi 12 of Nov. 9/43.)

Great interest is at present displayed in the T.26 Tank, a machine weighing 90,000 to 95,000 lbs. Should this go to production, as at present planned, the power/weight ratio will be approximately 12 HP/long ton, which can scarcely be considered adequate even when an infinitely variable transmission is fitted.

It is apparent, therefore, that one of the imminent problems for the U.S. is the provision of a satisfactory engine developing around 750 HP and fitting into a low silhouette machine.

The first and most likely engine to fulfil this role is a 12 cylinder version of the Ford engine. Three engines of this type were originally built for the British against a requirement placed in March 1942, but never released by the Ford Company. They are now being further developed by Ford.

It is probably worthy of note that, owing to the increased engine length, the 12 cylinder Ford can only be accommodated in the T.26 Tank if a shorter transmission can be developed or if the tank is lengthened.

The only other engine which appears to be within sight which will fulfil the power unit requirement for a low silhouette vehicle is the Chrysler 60°V 12 cylinder liquid cooled engine. This engine, having a bore/stroke ratio of $5\frac{1}{2}$" x $5\frac{1}{2}$", is constructed entirely in cast iron, with consequent high weight by comparison with Ford or Meteor engines, and is basically $6\frac{1}{2}$" longer than Meteor. In view of the present free supply of light alloys, it is unfortunate that cast iron has been selected.

Two engines have been built and a horse power of 650 obtained at 2,600 R.P.M.

Fords have obtained so much experience on the 8 cylinder installation in Medium Tank M4A3, however, that it seems somewhat improbable that the Chrysler engine can overcome the handicap of a late start.

Dealing with the remainder of the engines installed in Medium Tanks, it is agreed that the high standard of reliability of the Chrysler multiple-bank engine is the direct result of first class development work by the Chrysler Company, but that the Ford Engine, being a simpler power unit, will soon take first place.

Leader in the field of Light Tank engines is the 120 HP Cadillac V8.

In the current M5 Tank and the projected T.24 series two of these engines are harnessed to the hydramatic transmissions.

In order to provide a better power/weight ratio an experimental installation is in hand for T.24 using the Continental C 975 engine of 340 HP together with a Spicer gearbox. This, of course, will not be allowed to interfere with the present T.24 programme.

The Cadillac engine, however, may be considered a well tried and robust unit, one of its virtues being that, although governed to 3,400 engine R.P.M. in T.24, it is capable of running up to 4,800 R.P.M. for short periods without breaking a crankshaft or flying asunder due to high inertia loads. Chrysler Straight 6 Engine, rival for choice as power unit in the British carrier is, for reasonable reliability, limited to 3,200 R.P.M. giving a gross B.H.P. of 98.

The Chrysler Corporation themselves have insisted that the speed be limited to this figure in order to give the engine a satisfactory life.

A number of other engines are under consideration for Tanks in the U.S. but it is not felt that it would be of general interest to include them in these notes. They include

Caterpiller Diesel RD 1820, an air cooled radial engine developing 480 HP.

General Motors 12 cylinder 90°V Diesel, basically a two bank version of the 6-71 two stroke engine.

DISCUSSIONS OF THE VARIOUS MATTERS COMPRISING THE TERMS OF REFERENCE AND SUMMARY OF RECOMMENDATIONS ARISING THEREFROM.

N° 1

TO STUDY THE DEVELOPMENT AND PRODUCTION PROGRAMME OF TANKS IN U.S.A.

(A) ASSAULT TANKS

It was not until the latter part of our visit that we were able to obtain any official information with regard to the U.S. approach to the problem of a heavy Assault Tank meeting the British General Staff requirement.

General Barnes stated that still no interest was being shewn by the U.S. Army Staff in such a Tank but that, chiefly as a result of British pressure, preliminary consideration has been given to such a project.

The proposal is to mount a 105 m.m. high velocity gun stated to be capable of firing a 45 lb. projectile at 3,000 feet per second. It is not intended to use a conventional turret and only limited traverse would be provided. The armour under consideration is of six inches actual thickness arranged at an angle which would give protection equivalent to eight and a half inches. A uniform basis for front and sides would be provided.

Inclination of the armour to this extent would restrict internal space and the crew, would therefore be limited to four men. The Ford 8 cyl. engine and the electric transmission would probably be used giving a speed of say eight miles perhour. It is thought that this machine would weigh at least 170,000 lbs.

General Barnes expressed considerable doubt with regard to the practicability of such a machine chiefly because of transportation difficulties and because of the vulnerability of tracks and suspensions to mines and H.E. attack.

General Barnes did not believe that a prototype of such a machine could be completed in under 8 months. In our opinion this could be achieved only if the utmost enthusiasm was displayed by all concerned and if the project was granted the highest priorities.

The Only U.S. design on which active work is proceeding and which can be defined as falling within the general Assault Tank requirement is T.26.

The T.25 although similar in design is deficient in armour.

It has only been possible for the Mission to view these machines in mock-up form, and it appears unlikely that pilots of either will be running before the end of the year.

It seems likely that the weight of T.26 will come out at 90,000 to 95,000 lb. while it is claimed that T.25 will be some 20,000 lb. lighter.

The main difference between them is one of armour thickness, and a wider track on T.26 to accommodate the increased weight.

It is of the utmost importance to remember that whereas T.25 with an overall width of 124" (over tracks) will negotiate the Bailey Bridge,

T.26 on which this width is increased to 134" falls outside the prescribed limit.

The speeds of the machines are given as 32 and 27 M.P.H. on T.25 and T.26 respectively.

The high speeds proposed have already been commented on under "General Impressions".

Each machine is of course capable of carrying a gun up to the 90 m.m. piece.

	T.25	T.26
Maximum frontal protection on the hull is:	3" at 45° to vert.	4" at 46° to vert.
turret is:	3.5"	4"

For further comment on armour distribution see "General Impressions".

As already mentioned the success of these machines is entirely dependent on that of the Torqmatic or Electric transmissions and of the suspension. So far the U.S. have had very limited experience of carrying vehicles of these weights at the proposed speeds on steel tracks.

The low silhouette of these machines calls for a design of engine which can only be fulfilled at the present moment by the Ford V.8.

The mock up reveals a very practical approach to the problem of constructing a Tank in this difficult classification.

There is however one feature in particular which we view with some apprehension. Escape doors have been provided in the floor of the forward compartment and there would appear to be a serious risk of these being torn out by mine blast. Furthermore, the opening of these doors in the case of fire is likely to provide an updraught which would transform a minor fire into an intense blaze almost instantaneously.

The general impression of the fighting space available was good, but this has only been achieved by adopting under floor stowage and a drastically cut away basket floor, the hazards and disadvantages of which are referred to under Item 4 of the terms of reference.

The layout provides for three men in the turret and no consideration has been given to the possibility of requiring two loaders to deal with the heavy rounds.

Consideration has been given to the desirability of placing an immediate order for a substantial number of T.26 Tanks for the British, on the grounds that such a demand would accelerate development. To date the U.S. Ordnance have ordered only 40 T.25's and 10 T.26's.

Whilst we feel very strongly that every encouragement should be given to the U.S. Authorities in the development of this most interesting project (T.26), there are certain reasons why we feel that the placing of an immediate order by the British might have

undesirable repercussions. If, however, the British General Staff consider that a machine to this specification would go some way towards meeting their requirement for an Assault Tank, we would recommend that the U.S. be informed that a definite requirement for say 1,000 such machines exists. This would be followed by a firm order as soon as the Americans decided that the development had reached a stage where it was reasonable to go to production.

Although no active development is now taking place on the T.14, this machine also approaches the general Assault Tank requirement, but in its present form cannot carry a gun heavier than the 75 m.m.

Despite the fact that two pilot models were constructed many months ago, neither has yet covered 500 miles, and little interest seems to be shewn in the project.

As pointed out by General Barnes the advent of T.26 leaves this machine outmoded in practically every respect, therefore, the chances of its ever being brought to the production stage are extremely remote.

The continuance of interest in T.1 (now known as M.6) 40 of which are under construction, is solely due to the desire of U.S. Ordnance to obtain extended experience with large heavy tanks.

Of these forty machines twenty are to be equipped with torqmatic and twenty with electric transmission, and all are powered by the 900 H.P. double bank radial Wright engine.

In spite of the incorporation of a centre guide lug the vehicle, in certain circumstances, still sheds its track.

It is recognised that a Tank of this size and type with its comparatively light armour protection is never likely to see active service.

(B) MEDIUM TANKS

From conversations with General Barnes and others there appears to be no doubt that the U.S. forces will rely for medium tanks on the present M4 Series and on new variants of this Series for use in battle during 1944.

The most important variant of the M4 Series is that which carries the 76 m.m. high velocity gun mounted in the turret which has been designed for the new low silhouette T23 medium tank referred to below. Examples of this new M4 have been examined by the Mission. The general fighting arrangements are similar to those described for the T.23 later in the report. In our opinion the general layout of the turret and mounting is good. This project appears to be an excellent solution to the problem of getting the 76 m.m. high velocity gun mounted in a medium tank and available for fighting early in 1944. The maximum weight of this machine will not greatly exceed that of certain current machines because there is no intention to use the very heavy Chrysler multi-bank engine in this variant.

It is of interest to note that it was originally proposed to mount the 76 m.m. gun in the existing M4 turret and prototypes were constructed. One was in fact inspected by the Mission.

General Christmas stated that one maker will commence production on Jan. 1st, 1944, and other makers on Feb. 1st. As stated in B.A.S. Situation Report No.16, 500 machines are due for completion by March 31st. General Christmas estimates that 25% of the 1944 production of medium tanks will carry the 76 m.m. high velocity gun, most of the remainder will carry the 75 m.m. gun and the balance the 105 m.m. Howitzer.

The only successor in sight to the M4 Series of medium tanks is the new low silhouette, rear drive T.23.

As a result of its lower silhouette and of its somewhat heavier armour basis this machine will be considerably less vunerable than the M4 Series.

The feature of this machine which excites the greatest interest in the U.S. is its electric transmission, which is dealt with in some detail in Appendix 1. The case with which this machine can be handled is most impressive and must be experienced to be fully appreciated. Its high speed in reverse is regarded as a valuable tactical asset. U.S. Ordnance, and General Barnes in particular, are extremely enthusiastic and confident of the success of this transmission.

It is most interesting to note that this machine is designed for a maximum speed of 35 M.P.H. as compared with approximately 25 M.P.H. for the M4 Series, although the same suspension and track is employed. It is possible that this will be replaced later by a new design of horizontal volute spring suspension, of which samples are now being made.

It appears that refrigerating equipment for this tank is no longer under consideration, but pressure ventilation is under active development, particularly for use in the tropics.

Two pilot machines have been built and tested over a distance of approximately 4,000 miles each. We have been assured that the troubles experienced were in the main not associated with the electric transmission. Furthermore, they were not of a nature to occasion serious concern.

Up to the present only 250 of these machines have been placed on order. Production is due to commence at the rate of 35 per month in April 1944.

Three reasons are given for limiting the order to these figures:-

(1) No specific requirement has been expressed by the military authorities, although Gen. Barnes is hopeful that this will be forthcoming.

(2) The facilities available at General Electric are limited, and at the present time this company is reluctant to accept responsibility if the transmission is manufactured at other plants.

(3) The copper shortage is occasioning serious concern. This point was emphasized by General Marshall, who drew attention to the increasingly heavy demands arising from the aircraft and shipbuilding programmes.

The T.23 medium tank, with its low silhouette, improved armour, 76 m.m. gun, and impressive transmission system, is a most interesting development, and one which should receive all the encouragement which the British can offer. We have already suggested by cable that 6 of these tanks should be ordered without delay for the information of British users.

(C). LIGHT TANKS.

The M5, samples of which are undergoing trials in England at the present time, is the only Light Tank in current production in U.S.

The T9E1 Light Airborne Tank can hardly be said to be in production. Some 60 have been made but difficulties have been encountered with the suspension, engine, clutch and transmission. Although there is an order for 300 of these machines outstanding, production has been temporarily held up. It appears that considerable development work will be necessary before this is a satisfactory machine. Furthermore, in the opinion of the Mission, the design can hardly be described as being well balanced. Further information is contained in recent Situation Reports of the British Army Staff.

The sole interesting Light Tank development in U.S. at the present time is T.24, which is sponsored by Cadillac. This machine actually forms one of a series of armoured vehicles described by Ordnance as a Combat team. The latter includes gun motor carriages, anti aircraft equipment, a recovery vehicle and a cargo carrier. When the machine is adapted for these purposes the engine and transmission are brought forward into the space normally forming the fighting compartment. This is accomplished with little other change than shortening of the propellor shaft.

In order to illustrate the scope of this range outline drawings and particulars are attached at Appendix 9.

It will be appreciated that all these machines use a common set of major mechanical units, which, of course, greatly favours maintenance and service in the field, besides providing an attractive manufacturing setup.

The main features of this vehicle are a low silhouette keystone section hull with twin Cadillac engines, and twin Hydramatic transmissions operating through a manually actuated 2-speed transfer box feeding through a cletrac steering unit to a front drive.

The machine is carried on a new torsion bar suspension and a 16" rubber bushed steel track.

The armour basis is slightly less than that of the M5. On the other hand the machine carries a 75 m.m. gun as opposed to the 37 m.m. gun on M5. The ammunition is carried under the floor and protected by water jackets.

1,000 machines have been ordered by U.S. and production is expected to commence in May 1944. From this it is clear that the substantial order placed by U.K. has not yet been accepted by the American authorities. We have, however, already suggested by cable that six of these tanks should be requested from early production for trial in England. General Barnes indicated that such a request would be favourably received.

If the performance of the vehicle comes up to expectation it is intended that it will entirely supersede M5.

The expedient of using two engines and transmissions is possibly justified by circumstances. At the same time the complications and bulk which arise from such an arrangement do not result in an ideal layout for a tank application. Possibly arising in part from this, the weight of the machine, namely 37,000 lbs., seems excessive bearing in mind that the armour is no more than 1" at 30° frontal.

It is interesting to note that this machine has been designed for the unusually low ground pressure of 9.4 lbs./sq.in., and that the maximum speed is stated to be 45 M.P.H.

There is no doubt that the requirements of the Pacific theatre have had a large influence on the specification of this machine.

N° 2 TO ADVISE THE U.S.A. AUTHORITIES ON THE PROGRESS OF THE BRITISH PRODUCTION AND DEVELOPMENT PROGRAMMES

We have taken every opportunity of offering full particulars of British developments to the U.S. Authorities.

It must, of course, be remembered that whereas the British are in the market for U.S. fighting vehicles, the converse does not apply.

Details of specific developments which have been routed through Mr.Olley of the B.S.M. Detroit have, however, been received with great interest by the project officers concerned.

One item in which particular interest has been shown is the twin Oerlikon A.A. installation on Centaur. It has been suggested that a sample of this should be shipped over here for examination.

It has not been possible to discuss the Tortoise in any detail because at the date of our departure from England this project was in an extremely fluid condition. Furthermore we have found little interest displayed in large and heavy assault vehicles of this type.

N° 3 TO STUDY AND REPORT UPON THE POSSIBILITIES OF DESIGN AND LARGE SCALE PRODUCTION OF CARRIERS IN ACCORDANCE WITH THE LATEST GENERAL STAFF REQUIREMENTS

The Carrier situation has been the subject of considerable investigation, and various designs have been considered.

The T.16 is already in substantial production by Messrs. Fords at Boston, and this, with certain known limitations, should prove reasonably satisfactory.

On the other hand it can never meet the latest General Staff all purpose requirements.

The production commitments for this vehicle do not extend beyond the end of 1944.

At the present time Ford Windsor are manufacturing the Universal Carrier and were recently requested to change over to the Loyd Carrier.

As the result of trials Ford were reluctant to do this. They seriously criticised the construction of this machine and submitted a counter-proposal. This takes the form of an 8 wheeled version of the present Carrier with an improved weight distribution and increased body capacity

Before leaving England discussions took place with the Ministry of Supply with regard to the latest General Staff requirements. On arrival in this country discussions were held with General Barnes, and the proposal made that the design of a machine to meet this requirement would best be undertaken in the U.S. To this proposal General Barnes agreed in principle. The three projects mentioned above are discussed in more detail below.

T.16 CARRIER

The Ford plant at Boston, where these vehicles are produced, was visited by members of the Mission. This plant, which before the war was assembling trucks and cars, is now engaged exclusively on the T.16 Carrier. It is purely an assembly plant although they do weld up the body from finished plates.

The production rate is expected to stabilise at about 1,000 per month as from January 1944. At the date of our visit Nov. 8th, 1943, 3,000 vehicles had been shipped.

The final assembly line incorporates 52 stations, and it is stated that this could handle 75 per shift, with the necessary double shifting of sub-assembly operations, if the requisite labour could be allocated.

The design was evolved in Detroit by Ford in conjunction withB.S.M., the U.S. Ordnance being responsible for co-ordination.

The chief shortcoming of this machine is that when ascending steep inclines it is liable to rear up in a dangerous fashion. This is mainly due to the layout of the suspension, and also to the fact that the centre of gravity is too far back.

We have been informed that design changes are under consideration in Detroit in order to meet this criticism.

The use of Cletrac steering on this machine is an enormous advance on the braked differential steering of the Loyd Carrier. Track brakes are also provided for skid turns.

FORD WINDSOR 8 WHEEL CARRIER

The basic idea underlying this project is the employment of the maximum number of standard components already in production for the Universal Carrier. In this way the machine can be produced at very short notice in substitution for the present product.

The design is such that the carrying capacity is somewhat larger than that at present provided by the Loyd Carrier. Unlike the Loyd Carrier, however, this machine is provided with a very strong all-welded, bullet-proof plate hull. The thickness of plate used is 10 M/M front 7 M/M side. The upper portion of the hull is extended to enclose the rear shelf as on T.16, thus providing reasonable bouyancy. The Mercury engine and the standard Carrier transmission are fitted.

There are two alternative proposals for the rear axle:

1. The so-called Quad.6.5 ratio truck axle.

2. The Eaton 2-speed truck axle having ratios of 5.83 and 8.11.

The latter proposal is strongly recommended, should it prove satisfactory on test. Both of these axles are arranged to carry brakes increased in width to 3½ inches.

One vehicle of this type has already been shipped to England, and is presumably now fitted with the Quad axle as recommended by cable and undergoing test. Two further machines have been on shipboard for some time, but the vessel is unfortunately delayed in port at the time of writing (Nov. 24th,1943). One of these machines is fitted with the Quad axle, and the other with the 2-speed axle.

The Mission paid an early visit to the Windsor plant and witnessed a demonstration October 28th, 1943 of this machine running in company with the regular Universal Carrier and the T.16. The demonstration included the towing of a 25 pdr. field gun at high speed over rough going. It also included a demonstration climb up a very steep ramp (1 in 1.3). This demonstration showed up very clearly the tendency for the T.16 to rear up to an alarming extent. On the other hand the Windsor Carrier surmounted the ramp in a reassuring manner.

Members of the Mission took the opportunity of driving the machine over a cross-country course. They were impressed with the performance, apart from the steering. This particular machine was fitted with the original narrow brakes, and there is no doubt that these are grossly inadequate. The Ford organization are confident that the wide brakes will be satisfactory, but this remains to be proved by test.

Following this demonstration a conference was held, and a decision was taken to prepare 4 more of these machines for test, 2 to be fitted with the Quad axles, and 2 with the Eaton 2-speed axles.

The test was arranged to take place at Ottawa under the observation of Major Mills of the F.V.P.E. in accordance with the British Standard Schedule.

Mr. Wallace Campbell undertook to have these 4 machines dispatched by Nov. 15th, and he is to be congratulated on having met this date.

A cable was sent to the Ministry on October 30th, 1943 outlining the position and containing a recommendation that if the test results in Canada prove satisfactory, immediate contract action should be taken.

Members of the Mission were in Ottawa on Nov. 26th and took the opportunity of driving the machines which at that date had completed approximately 800 miles apiece entirely free from mechanical trouble. The 3½" wide brakes provided a more satisfactory control, being free from overheating and consequent brake-fade.

The disadvantages of the braked differential steering vis-a-vis the Cletrac as fitted to the T.16 were however, very apparent. Even when using the lower ratio of the two-speed axle, first speed had to be engaged when making a tight turn with a towed gun across country. It is considered that for the towing role at least, the two speed axle is essential.

In the opinion of the Mission this vehicle is a great improvement on the Loyd Carrier and makes a timely contribution to the Carrier situation. It should receive every encouragement.

It should be noted that no work has been done in connection with stowage arrangements. It is important that this matter should receive immediate

attention in England, and that Ford Windsor should be provided with full drawings and particulars with the least possible delay.

NEW CARRIER TO MEET LATEST GENERAL STAFF REQUIREMENTS.

The reason for the recommendation referred to earlier, that the design for this machine could be best undertaken in the U.S., is that the major components will, of necessity, be of American origin. It is, of course, obvious that a design can in this way be more effectively and expeditiously carried out with the co-operation of the various manufacturers concerned; a point on which General Barnes was in full agreement. He quite rightly insists that Ordnance can only undertake this project if full responsibility for design details and for development and test, is delegated to him. It was stated that should this recommendation be acceptable to the British, Ordnance would welcome a technical representative from U.K. in a consultative capacity.

A cable was dispatched on Nov. 6th, 1943 outlining the above proposals, and a reply was received dated Nov. 16th, 1943 gratefully accepting General Barnes' offer.

As is quite understandable, General Barnes is not prepared to commence work until he is supplied with outline drawings indicating the general proportions of the vehicle which is required, and also a reasonably detailed tentative specification. The information contained in the tank board paper R.T.B.111 (43) is not considered sufficient. This was pointed out in our cable of Nov. 20th, 1943.

The controlling factor with regard to this project is undoubtedly the availability of major components in the U.S. The matter of uniting these to form a suitable design is relatively simple. The availability situation has become appreciably more difficult even since the arrival of the Mission. It is seriously affected by the recent expansion of the wheeled vehicle programme and other urgent requirements.

In the cable referred to above, dated Nov. 16th, we were informed that a design was already in preparation in the U.K. using American components such as engine, gear box and steering units. It was pointed out that, in view of the large number required and of possible shipping difficulties, it was essential for Carriers to be built in the U.K. as well as in the U.S.

On receipt of this cable we dispatched a further cable dated Nov. 20th calling attention to the fact that it seemed probable that the U.S. and Canada could build complete Carriers to U.S. design in numbers sufficient to absorb all suitable major components available. British building would, therefore, be in partial substitution for the U.S. production, unless suitable alternative components could be found. We have asked the B.S.M. to investigate this matter of alternative components, a matter on which they are now busily engaged. It should be said, however, that preliminary investigations reveal no encouraging prospects.

With regard to the American design for this Carrier, preliminary talks indicate that the only engines likely to be available are the 6 cyl. Chrysler T.120 and the Cadillac V.8

In our opinion the Chrysler engine is much too small for this duty. It should be noted that the Chrysler organization, themselves, insist that for continuous duty this engine would have to be governed to a conservative speed at which the power output would be little more than that of the Ford Mercury, and therefore quite insufficient for this application. On the other hand the Cadillac engine delivers adequate power at a conservative speed, and is in our opinion very much more suitable.

The U.S.Ordnance expresses a strong preference for and great confidence in the Hydramatic transmission. Furthermore, it seems probable that this will be more readily available than any suitable conventional gear box, synchromesh or otherwise.

It should be appreciated that the final decision with regard to the allocation of manufacturing capacity of complete Carriers and for major components rests with the Army Services Forces.

N° 4 TO STUDY AND REPORT UPON THE LATEST AMERICAN DEVELOPMENTS OF GUN MOUNTINGS, TURRETRY AND GUNNERY PRACTICE, INCLUDING THE USE OF GYRO STABILIZERS.

The present and future tank programme in the United States is based on the following weapons:

(1) 75 mm gun

(2) 76 mm gun

(3) 90 mm A.A. gun modified for tank use

(4) 105 mm Howitzer

(5) 155 mm A.A. gun adapted for tank use

The 76 mm gun, having a performance similar to the British 75 mm 50 calibre tank gun, is very suitable as a dual purpose weapon having a good A.P. performance and being capable of firing a 15 lb. HE shell. No action has been taken in U.S. to reduce the Velocity of the HE round to give a better crest clearance when employed turret down, as is now under consideration in the U.K. No action appears to be in hand for the development of super velocity ammunition, such as composite rigid and sabot. In our opinion such development should proceed immediately having regard to the wide scale on which the gun will be introduced. This view has been expressed in the appropriate quarter.

The development of turrets and mountings for the 90 mm A.A. gun is an important item in the tank programme. The performance of this gun against armour according to the calculated data available is similar to that of the British 17 Pdr. at normal ranges and somewhat superior at extreme ranges. On account of its greater calibre the 90 mm gun is capable of firing a more effective HE round than the 17 Pdr. This role, however, could be filled by a much smaller and lighter single purpose weapon such as the British 95 mm Tank Howitzer.

The 90 mm gun is some 300 lbs. heavier than the 17 Pdr. while the APC round is approximately 4" longer and 7 lbs. heavier. The centre of gravity of the 90 mm piece is some 7" farther from the breech face and problems of balancing and inboard length are more difficult. The 17 Pdr., therefore, is a more handy A.P. weapon for tank use.

The 105 mm Howitzer is being adopted in production as a close support tank weapon. The extreme shortness of this Howitzer has been made possible by utilising a special purpose mounting. On account of its rather larger projectile, it should be more effective than the British 95 mm Tank Howitzer. The desirability of the British armoured forces continuing to employ both these weapons for similar tasks requires examination. In any future project it may well be worth while to consider the advisability of adopting this handier U.S. weapon and enjoying the advantages of a common ammunition supply.

It appears that an adaptation of the 155 mm A.A. gun M1 and M1A is being considered as a possible successor to the 90 mm as a super heavy tank gun. It may, therefore, be regarded as a possible competitor of the British 3.7" 37 Mr. Very little work on its adaptation for tank use appears to have been completed so far. It is being mounted experimentally, however, on the chassis of Tank T.23 as an S.P. to fill a field artillery support role. There is also an A.P. projectile of 100 lbs. weight and 2740 ft/sec muzzle velocity.

GENERAL FEATURES OF U.S. TURRETS AND FIGHTING COMPARTMENTS

All U.S. Medium and Heavy Tanks are designed to incorporate the traverse ring originally employed in the M.4. The Recoil systems and cradles also cover a wide range of guns. A high degree of standardization has been achieved in this way.

TURRET DESIGN

The increase in the size of guns has led to considerable increase in the size of turrets and in view of the high armour protection now being attempted turret weights are getting very great. The original M.4 gun mounting was designed with recoil cylinders on either side of the gun. This led to a relatively low turret silhouette on this vehicle which was most necessary having regard to the excessive hull height occasioned by the transmission layout. As the size of the weapon has increased, however, the side by side recoil layout has lost much of its attractiveness, and results in cramping the gunner and loader. It is considered that a more convenient arrangement could be achieved by locating the buffer and run out presses under the gun barrel as has been done in the 17 Pdr. Cromwell S.P. or alternatively by using a concentric design of recoil system. Some work has been done on the latter, but development is not yet complete.

In our view the latest designs of turrets to accommodate the 76 mm and 90 mm are wasteful of armour. Suitable redesign would permit a much higher standard of protection, or alternatively a saving in weight.

Turrets designed for recent machines are of poor shape. Their sides slope out from the base and provide a deflector for AP attack likely to cause penetration through the hull roof. The rear bulge of the turret has been made large to achieve balance. The sloping base of this bulge in particular forms a dangerous deflector likely to cause penetrations. The shapes of the mantlet and rear bulge are such as to confine HE blast with risk of damage to drivers doors and engine covers. The general protection of turret races is not up to latest British design standards. It will be remembered that this type of defect was one of the main reasons for the rejection of the recent design of turret for the 17 Pdr. on Cromwell. It was also the reason for many of the defeats of the German Mark VI in Africa.

GUN MOUNTING DESIGN.

All gun mountings are designed with twin recoil systems, one on each side of the gun. With the larger guns this leads to considerable spreading of the gun mounting and extravagant utilization of the space available.

All current and experimental designs employ an external mantlet. This tends to make the turret balance problem more difficult and leads to an increase in weight. It is suggested that for heavily armoured vehicles the internal mantlet with slotted shield is more economical and more robust under heavy attack, but the oft expressed user preference for the external mantlet is a psychological factor which must not be ignored.

The frontal protection of U.S. mantlet is impaired by the lack of a suitable external pupil sight and large sight apertures some 2 in. diameter are needed. It is important that a suitable external pupil instrument be developed for the heavily armoured vehicles.

The heavier weapons such as the 76 mm, 90 mm. guns, and 105 mm Howitzer are only provided with partial recoil guards, and the risk of injury to crew members is likely to be serious, although it must be admitted that the partial guard greatly facilitates loading. An improved guard will be needed if it is necessary to conform with present British standards.

The 90 mm gun is provided with a vertical sliding block and is loaded from above. As already mentioned, the cradle assembly is identical with that used in the 3" M.10 and 76 mm gun mountings. Adoption of side loading with the 90 mm gun would have necessitated a special layout of cradle and recoil system which Ordnance were anxious to avoid.

In consequence of this and the length and weight of the 90 mm round, loading will be difficult, particularly at depression, and the rate of fire will be proportionately reduced.

On account of the smaller breech ring side loading has been possible with the 76 mm gun.

Elevation gears are of simple design employing arc and pinion with fixed centre hand wheel control.

The hull mounted machine gun is retained, but there is still no sight even on the latest designs. In consequence the gun does not add appreciably to the fire power of the vehicle whilst its mounting constitutes a weakening of the front plate which is a serious consideration on heavily armoured vehicles.

FIRING GEARS.

At present all firing mechanisms employ electric Solenoid operation with foot control. A hand operated mechanical system is provided for emergency use. A redesign of this scheme has been produced with Solenoid operation but using finger control from the traverse handle.

This arrangement has been released for all tanks, and supersedes all Solenoid foot operated mechanisms. Mechanical foot firing is provided for emergency use.

On the British A30 mounting a safety switch is provided in the Solenoid circuit. The desirability of a similar device for the U.S. 90 mm mounting was discussed. Ordnance are in favour of its use but Armoured Force users have opposed its introduction. It was stated that a design of switch exists and samples have been made and could be fitted to any tanks supplied for British service.

FIGHTING COMPARTMENT AND STOWAGE.

The danger of ammunition fires has been recognized in all the latest designs. Water blanketed receptacles are employed and every effort has been made to stow ammunition low. In those tanks mounting the 90 mm gun lockers for banks of three rounds are provided below the fighting compartment floor. On either side of the fighting compartment and over its full length are chambers providing water blanket protection. The turntable has been cut away to give access to the ammunition, and only provides a platform for the gunner and commander on the right hand side of the mounting. The loader stands on the hull floor. While fire risk has been substantially reduced, the inaccessibility of the ammunition leads to considerable reduction in rate of fire and fighting efficiency. The danger of injury to the loader from the cut away rotating platform appears pronounced, and the risk of jams due to trapped spent cases or fouls with locker lids is likely to be serious.

The arrangement of stowage is such that very little ammunition is handy in a ready position. In most cases only two rounds can be reached by the loader for immediate use. Further supplies involve laborious removal of ammunition from stowage bins, a process likely to be seriously criticised by British users.

Floor stowage is also employed with the 75 mm, the 76 mm, and the 105 mm ammunition. While the 90 mm round has been stowed horizontal on account of its great length, the 75 mm round has been stowed vertically below the floor on M.4 vehicles. The 76 mm and 105 mm ammunition is stowed grouped in bins inclined to the floor. These bins are each provided with water blankets.

The 90 mm ammunition is inaccessible mainly on account of the need for horizontal stowage bins. The 75 mm and 76 mm rounds are far more easily reached, and the 105 mm Howitzer ammunition is quite reasonably handy.

Ordnance state that water blanketing greatly reduces the likelihood of fire and they also claim that when a fire does result from armour defeat there is an appreciable time lag before it takes hold.

Even with the heavier weapons, such as the 90 mm gun, the crew is limited to three members only, and when it is remembered that the 90 mm round is heavier and larger than the 17 Pdr., it is doubtful if three men will fight this gun efficiently.

This matter was discussed with General Barnes, who expressed considerable interest, but stated that so far he had received no request for an additional loader from U.S. users.

It should be noted that the introduction of a fourth man in the turret would not be feasible with the present stowage and cut-away platform arrangement.

AIR CONDITIONING AND GAS PROTECTION

Ordnance had hoped to reduce danger to crews from poison gas by providing pure air to the fighting compartment from a gas filtration unit and maintaining a positive pressure in the compartment. Trials have shown, however, that this is not immediately practicable on account of the large delivery of pure air required to maintain a positive pressure and owing to the difficulties encountered to date, no early models will appear incorporating this feature. U.S. Ordnance have rather lost interest in this solution. An alternative project is in hand, however, which has for its object the supply of pure air under slight pressure to each member of the crew individually, each man being provided with a special face mask.

A scheme for air conditioning tanks for tropical service is also being tested. In this scheme also, conditioned air is supplied to each member of the crew individually. Air from a conditioning unit is fed into a special light suit of clothing. The supply point is above the head and the air travels downwards.

All trials so far carried out indicate that air conditioning of the whole fighting compartment is not practicable.

TANK FIRE CONTROL AND VISION DEVICES -

COMMANDERS CUPOLA

The Medical Research Laboratory, in conjunction with T.A.C., have evolved a new form of commanders cupola which appears superior to anything else so far produced in Britain or America. It is a flat type of cupola approximately the size of that employed in the Churchill tank. The top consists of two semi-circular doors giving access to the turret. In one half door a periscopic look-out is provided. The periscope embodies a telescope which permits the commander to lay for line when shooting turret down.

Around the periphery of the cupola are located a number of wedge-shaped glass blocks embedded in the armour. It is claimed that the blocks have high imunity to attack by 0.50 calibre Machine Gun at point blank. The wedge formation of the blocks would increase their resistance to attack, and the small size would make the chance of a hit by anything larger than Machine Gun bullets unlikely.

The faces of the fixed glass blocks are so inclined that refraction of light while passing through permits the commander a wide field of view from slightly below horizontal to well above. Probably the most serious criticism that can be made is that objects close to the Tank cannot be seen. Samples of these cupolas should be sent to England as soon as possible. Full drawing information has been obtained.

SIGHTING TELESCOPES.

The original M.50 series of telescopes is now regarded as obsolete and is to be replaced by the M.70 series having improved optical qualities. The M.70 series of telescopes will in time be superseded by the M.71 and M.72 types previously identified by the experimental numbers T.92 and T.93.

The M.71 has magnification 5 and field 13°, and M.72 magnification 3 and field 21½°.

The optical quality of even these latest instruments is much inferior to that of British sights and definition is poor except near the centre of the field.

A special visit was paid to the Frankford Arsenal which is the development centre for fire-control instruments. Impressions gained during this visit confirmed those already formed at Fort Knox.

The Armoured Force board "Maze" graticule, as used on the M.71 and M.72 instruments, is considered to be confusing and likely to be severely criticised by British users. As already mentioned, gun mountings are designed to have a large aperture in the armour some two to three inches in diameter for the telescope and the danger of damage from machine gun fire is a serious consideration. It appears that the optics of the telescope requires the provision of a large aperture.

Alignment adjustment for the telescope is provided on the telescope bracket.

Since it is vital that tanks should have sights of the highest optical quality it is suggested that consideration should be given to the problem of equipping U.S. Tanks in British Service with British sights.

PERISCOPIC DUAL SIGHT

The Medical Research Laboratory at Fort Knox have designed a periscopic sight with two powers of magnification. Unit power is provided for close range fighting and six power for long range gunnery. Transition from long to short range is obtained by inclining the eye through 15 degrees. The periscope is linked to the gun by a spring loaded system to eliminate backlash.

The design has been worked out very efficiently. The instrument should meet the long standing user requirement for a dual sight very satisfactorily. It is felt, however, that the magnification of six is too high for general work.

All available data on this sight has been obtained and it is recommended that Britain should produce a similar sight as soon as possible. Samples of the U.S. sight should be sent to England as soon as they are available.

For turret down shooting the azimuth indicator and elevation quadrant are provided. A simple open sight is mounted on the hull roof to permit the commander to lay for line.

In future tanks this sight will be duplicated in the periscope in the commander's cupola. The cupola also will be provided with its own rough traverse indicator in the form of a traverse scale surrounding its periphery beneath the turret roof.

The azimuth indicator is a simple and satisfactory instrument. It is driven from the traverse rack through a spring loaded split pinion to eliminate back lash, and is similar to the British design. The Elevation Quadrant consists of a small bracket mounting a sight clinometer which can be driven in elevation and depression by an adjuster knob and worm.

There is no throw out for the worm drive and it is likely to be tedious in operation when large quadrant elevations have to be applied. The scale is simply calibrated in mills so that use of range tables is essential before a final setting can be made. It is considered that the British design embodying sight clinometer and range drum is more satisfactory. The British design has yet to be provided with a throw out for the worm to give quick resetting.

It is understood that six power binoculars are to be provided for observing fall of shot but it has been suggested that these will not be necessary when the six power periscopic sight is used. This point of view cannot be agreed since the sight is inoperative when turret down and in any case observation is the business of the tank commander.

No telescope is provided for identification of targets. Some thought has been given to the possibility of using a power ten telescope similar to the British No. 14 but introduction of such a telescope cannot be effected for a very long time. Britain must, therefore, provide her own identification telescopes for U.S. tanks in British Service.

TRAVERSE CONTROL

The Oilgear traverse appears to be standard for all future vehicles. It is understood that modifications have been made to traverse gear boxes to ensure that they will be suitable for the heavier duty likely in the future. Modification has been made to the control cam of the oil gear unit, and Ordnance state that this has resulted in much improved control. Apart from gear boxes, no basic change has been made elsewhere in the equipment.

GYRO STABILIZERS.

The Junior Stabilizer on the Centaur Tank was inspected. The installation has been very neatly carried out. Control of the gun appears very good and much better than the stabilized mounting on the M.4. It was impossible to assess the standard of efficiency obtained since no comparative trials have been carried out and no results have been recorded. Trials now being carried out in England will indicate the standard reached and the Centaur equipment is being sent to England immediately so that trials under identical conditions can be made for comparative purposes.

Three designs for a combined elevation and azimuth stabilizer are being worked out by three separate firms but it is unlikely that any of these will be available for some time. All designs embody the use of free rate-measuring gyroscopes and are being produced on basically similar lines.

N° 5 TO STUDY AND REPORT UPON THE AMERICAN DEVELOPMENTS OF ANTI-AIRCRAFT EQUIPMENT ON TANKS.

It is noteworthy that U.S. designers consider it desirable to provide tanks with specially mounted machine guns for their individual A.A. defence but have so far failed to consider the need for a special A.A. Tank.

Individual tanks are equipped with a single .50 Browning Machine Gun for self defence. The gun is freely mounted on a scarff ring and is operated by the commander or loader. To fire the gun effectively, the gunner must expose a considerable amount of his body. The desirability of producing a mounting allowing greater protection for the gunner was discussed with T.A.C. Officers, and it is believed that an attempt will be made to evolve something.

The British case for the special A.A. tank was explained to T.A.C. designers, and it is understood they will now consider the design problem. Ordnance are anxious that a sample of the British Twin 20 mm. mounting should be sent to the U.S. so that designers can study its features. It is recommended that this action be taken at once and that a complete equipment under the supervision of a suitably trained officer should be sent to Aberdeen immediately, and later Fort Knox, or alternatively a sample to each establishment.

The necessity of providing adequate apparatus for analysis of firing results was explained to T.A.C. who agreed that such apparatus was essential. It is recommended, therefore, that a complete report of the facilities available at D.T.D., H.M.S. Excellent, A.R.L. and elsewhere should be prepared and sent to T.A.C., and also to the Armoured Board Fort Knox, without delay. Ordnance also propose to send an officer to U.K. to study British designs on the spot.

Ordnance have also asked for the following items to be sent from U.K.:-

1. Two 20 M/M Polsten guns.
2. Two sample Polsten belt feed mechanisms.
3. Full particulars of the projected twin 20 M/M turret and mounting, and also the Metropolitan Vickers control gear.
4. Two 40 M/M Vickers 'S' guns, complete with samples of each feed device for right and left hand use. Five hundred belt links and five thousand rounds of ammunition.

The Maxon turret, which is known in England, has now appeared in a somewhat larger form capable of handling quadruple .5 Brownings or twin 20 M/M Oerlikons. It is proposed to use these independently driven mountings on trailers for air field defence, etc., and on half tracked vehicles. No project exists for incorporating these mountings on tanks or fully tracked S.P. mountings.

N°6 TO STUDY AND REPORT UPON AMERICAN DEVELOPMENT OF S.P. MOUNTINGS IN RELATION TO BRITISH GENERAL STAFF REQUIREMENTS

Originally gun motor carriages mounting high velocity weapons were designed as the armament of the Tank Destroyer Force. It now appears that these equipments are viewed as pure anti tank weapons along similar lines to the British General Staff policy for S.P. anti tank guns. They do not comply in detail with British users' ideas, particularly with regard to fire control.

Ordnance are submitting many types of support field artillery gun motor carriages, but so far as these are concerned there does not appear to exist any clear user policy. Silhouettes are high compared with the equivalent field carriages. As designs none of the support gun motor carriages can be compared with the British 95 M/M Infantry S.P. and it is recommended that an example of this equipment should be sent to the States as soon as it is available.

The following are the principal types in production or under development in the U.S.A.

3" Gun Motor Carriage - M.10

This vehicle is already in British Service and numbers are available in England.

76 M/M Gun Motor Carriage T.70

General Particulars:

Weight	39,500 lbs.
Crew	5
Max.Speed	50 M.P.H.
Armour	Front 1/2",Side 1/2",Rear 1/2" Turret front 1", Turret side 1/2"
Armament	76 M/M gun - Elevation 20° Depression 10° Calibre 0.50 Machine Gun HB M2. 4 Calibre 0.30 Carbines M.1.

This equipment was designed from the ground up for the Tank Destroyer Force and is not a converted tank.

The high speed of 50 M.P.H. which has been achieved, was specified as an important userrequirement.

350 Vehicles approximately have been completed out of the initial order of 2,500.

Both turret and hull are of welded construction and are in 1/2" thick bullet proof plate.

The turret is supported on the standard traverse ring with 68" clear diameter, and is provided with all round traverse.

The standard recoil system, with duplicate cylinders on each side of the gun, is used.

The gun and its cradle has been inclined 45° to the right to simplify loading. In order to increase the space available for the gunner the gun axis has been positioned 2" to the right of the turret centre line. It was stated by the project officer that the turret had a tendency to throw off for line when firing with hand traverse. This tendency, however, is not noticeable in power traverse.

The sight bracket is equipped with a magnification 3 telescope. There is no provision for central laying or open sights. The normal tank elevation quadrant is fitted but there is no provision for an open sight for the commander, nor is there a dial sight. A crude vane sight is, however, provided on the turret roof.

Solenoid foot firing is used, and also a hand lever above the cradle for emergencies.

The elevation control is satisfactorily positioned. The power traverse control is directly in front of the gunner's chest and awkward to use. The hand traverse control is on the gunner's left and is too far to his rear for efficient operation.

A long fixed guard is provided to give protection from the recoiling breech. This guard is clumsy and takes up much space.

All ammunition is stowed in open containers. A total of 47 rounds is carried. Eleven rounds are in a bin in the front of the turret on the right of the gun breech, and are intended for immediate action. The remaining rounds are carried in panniers on each side of the hull.

A single 0.50 calibre Browning machine gun is carried on a scarff ring mounting above the commander for A.A. defence.

There is no platform in the fighting compartments but travelling seats and foot rests are provided for the gunner and loader.

The general layout of the turret and fighting compartment, although not ideal, is considered a workable job. Crew fighting space is somewhat limited.

The fire control arrangements and turret and mounting controls fall short of present British ideals. The protection has been reduced well below the minimum considered necessary by British users in order to give the high speed of 50 M.P.H. In this connection it is worthy of note that General Barnes stated categorically that in his personal view gun motor carriages should carry armour no more than that required for protection against splinters.

90 M/M Gun Motor Carriage T.71

General Particulars:

Weight	66,000 lbs.		
Crew	5		
Max.Speed	30 M.P.H.		
	Hull	Above Fender	Below Fender
Armour	Front	1½"	2¾"
	Side and rear	¾"	1"
	Turret		
	Front and rear	1½"	
	Side	1¼"	
Armament	90 M/M gun M3		
	.50 calibre machine gun HB. M2		
	5 -0.30 calibre carbine rifles M.1		

This machine is based on the standard M4A2 tank chassis.

The 90 M/M gun has been installed in an all round traverse turret supported on the standard M4 traverse ring. The recoil mechanism employed is that used on the 3" gun motor carriage M.10, and with the 75 M/M gun on T.70 with suitably adjusted buffer port openings and stiffer springs.

The installation was seen in a metal turret on an actual vehicle, but was very incomplete as regards details. The gun is mounted for top loading, and arrangements for traverse control, mounting control and fire control were generally similar to those on M.10 and T.70.

Fighting space appears adequate for a crew of three, but it has yet to be established that three men can fight a gun with ammunition as large as this efficiently.

It has been suggested that the hull may be suitable for the installation of the 17 Pdr. gun in the S.P. role. A turret similar to that already evolved in England would be suitable. It is most unlikely that U.S. would be prepared to undertake this work, but it is believed that Canada would handle the pilot installation and such production as her limited resources would permit.

The armour protection available falls short of British requirements. Increase in protection might be obtained at the sacrifice of speed, but the present feeling in U.S.A. is that this type of vehicle requires a high maximum speed.

155 M/M M.1. and M.1.A1. GUN MOTOR CARRIAGE

A design is being prepared for an experimental S.P. mounting for the 155 M/M high velocity gun on the chassis of Tank Medium T.23. The design was not seen and it appears that the equipment is being submitted as an Ordnance project. It is intended to fill a field artillery support role and the gun can also fire a 100 lb. A.P. projectile at 2,740 ft/sec.

MX COMBAT SERIES

Ordnance have submitted a whole range of gun motor carriage equipments designed around the mechanical components of Tank Light T.24. So far U.S. users have shown no enthusiasm for these equipments, and no plans a are laid for production of any of them.

Twin Bofors A A Equipment - T.65E1

40 M/M Bofors guns are mounted coaxially and are arranged for simple eye shooting. The gun mounting is surrounded by a light bullet proof shield, which is inadequate except to resist attack by S.A.A.

A large complement of ammunition is carried and some 50% is stowed in bins all round the mounting shield, and the remainder in bins at the bottom of the hull.

The equipment is only suitable for defence of fixed positions, or for use on L of C, a role which could be filled more economically by a wheeled mounting. The system of fire control, which is simple eye shooting, is not suitable, and on this point Ordnance agree. The possibilities of the No. 3 Predictor Stiffkey Stick and gyro sight were discussed with them, and they are very anxious to be supplied with all data available. It was agreed that this information would be sent out as soon as possible after the Mission's return to England.

155 M/M Howitzer T.64E1 90 M/M Gun Motor Carriage

4.5 Gun T.16E1

105 Howitzer T.76

In these designs existing field carriages have been adapted for installation on further variants of the T.24 light tank chassis. They are intended by Ordnance to fill field artillery support roles. U.S. users appear to show no interest in them, and the equipments do not meet any known British require ment. The guns are mounted to shoot over the front of the vehicle with very limited traverse. A good complement of ammunition has been allowed for.

A series of illustrations of these equipments is attached at Appendix 9.

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N° 7 TO ADVISE THE U.S. AUTHORITIES ON THE LATEST DEVELOPMENT OF D.D.

A preliminary discussion took place with General Barnes and he appears to be of the opinion that the elaborate mechanism involved by the D.D. approach is not warranted by the requirement. He is very much more interested in the means of flotation and thinks that sufficient propulsion can be provided by making use of the tracks with the possible addition of channelling. Alternatively, he is prepared to consider the use of tugs.

A film was shown to the officers concerned at the Tank Automotive Centre and this with all the relevant particulars was left with them.

VISITS TO CANADA

In accordance with the original plan an early visit was paid to Ottawa. The object of the Mission was explained and details of British development were discussed at a meeting with the C.G.S., Gen. Stewart, in the chair. The various directorates concerned were fully represented.

Subsequently the Proving Ground was visited and various vehicles including the M8 Armoured Car were driven over the course. The Proving Ground provides a good variety of conditions and includes an artificial rock course intended to reproduce the conditions of Hungry Hill, but it was regarded as being too severe and an alternative natural rock course was inspected and recommended. The very keen spirit of all those concerned calls for favourable comment.

A visit was also paid to the Montreal Loco Works who are engaged in the manufacture of M4A1 and the Sexton. The latter mounts a 25 pdr. on the M4 chassis, and, accommodating gun, crew and driver in one compartment, provides a roomy and workmanlike S.P. vehicle.

We were much impressed by the layout of the plant, which was built specifically as a Tank Shop, and which compares favourably with the biggest and best available in England. Members who had visited Montreal in early 1942 noted that considerable progress had been made since that time. No plans have yet been issued to Montreal Loco for fitting the 76 mm gun in M4 nor will they be unless the numbers are extended beyond the present order. In fact, unless further orders are placed in the near future Tank work will cease entirely by June 1944.

A further visit was paid to Canada at the special request of Gen. Stewart to report on our contacts in the U.S. and to give them a summary of our impressions. This took place in Ottawa on Nov 25 where members of C.G.S. and various directorates concerned in design, production, and testing were represented. Brochures and reports dealing with British developments were left for their information. A film of D.D.Sherman, Scorpion, Cromwell and W19 trials was shown.

The Canadians were very appreciative of the trouble we had taken in visiting them a second time.

The opportunity was taken of driving the two Windsor Carriers which are now undergoing trials. Further information is contained under Terms of Reference 3.

After discussion with the Canadian Authorities it was decided to allocate to the Dominion Bridge Co. the project of installing the 17 pdr. in the M10 turret. This work now appears to be progressing satisfactorily. For further particulars see Terms of Reference 6.

SUMMARY OF RECOMMENDATIONS

GENERAL RESEARCH AND DEVELOPMENT

We are convinced of the absolute necessity of continuing research and development in England in connection with A.F.V's.

Everything possible should be done to encourage this work and a vigorous policy for producing improved types should be pursued.

Whilst, with the above exception, no general policy recommendations are offered, there are a number of specific recommendations on which, in our opinion, action should be taken. All of these are covered in our notes dealing with the "Terms of Reference."

1. Arrangements for the shipment to the U.K. of the following vehicles as soon as they are available should be made.

   (a) Two tanks M6, one with Torqmatic and one with Electric Transmission
   (b) Six Tanks T23.
   (c) Six Tanks T24.

2. The following equipment should be shipped to the U.K.

   (a) One sample of the latest type of all-round vision commander's cupola.
   (b) Samples of periscopic dual sight.

3. The following vehicles should be shipped to the U.S.

   (a) One Centaur Tank with twin Oerlikon A.A. guns.
   (b) One 95 mm Infantry Self-Propelled Mounting.

4. The following equipment should be sent to the U.S.

   (a) Two 20 mm Polsten Guns.
   (b) Two sample Polsten belt-feed mechanisms.
   (c) Two 40 mm Vickers "S" Guns complete with samples of each feed device for Right and Left-hand use.
   (d) 500 belt links (Vickers S)
   (e) 5,000 rounds of ammunition. (Vickers S)

5. The following data should be sent to the U.S.

   (a) Particulars of the No. 3 Predictor, Stiffkey Stick and Gyro Sight
   (b) Report on facilities available at D.T.D., H.M.S. Excellent and A.R.L. for anti-aircraft firing result analysis.

6. If test results in Canada on the Windsor Carrier are satisfactory, immediate contract action should be taken, also immediate action regarding the stowage of the above vehicle should be taken in U.K. A vehicle should be fully stowed in the U.K. and sent to Canada.

7. The design of the new carrier to meet the latest General Staff Requirement should be carried out by the U.S. Ordnance.

8. If the British General Staff consider that the T26 Tank would go some way towards meeting their requirements for an assault tank, the U.S. should be informed that a definite requirement for say 1,000 such machines exists. This would be followed by a firm order as soon as the Americans decided that the development had reached a stage where it was reasonable to go to production.

9. Four vehicle sets of manganese dry-pin tracks for the M4 tank together with their appropriate sprockets should be sent from Montreal to the U.K. for trial at F.V.P.E.

APPENDICES

APPENDIX 1

AUTOMATIC TRANSMISSIONS.

THE ELECTRIC TRANSMISSION (GENERAL ELECTRIC CORP.)

This is a General Electric development sponsored by Chrysler for use on the T23 Tank, of which 250 have been ordered. The T.23 will be the first of the low silhouette tanks to go into production.

Chrysler are also working on a version of the T.25 incorporating this transmission, but, owing to the increased weight, this development hinges on the success of their new suspension system. (Horizontal Volute).

ELECTRIC TRANSMISSION AS APPLIED TO T.23

(a) General Layout.

The T.23 is laid out for rear drive and the arrangement of the units is as follows:

(i) Engine (Weight 1330 lbs.)

Ford G.A.N. installed with flywheel toward rear.

(ii) Main Generator (Weight 2070 lbs.)

Unit-mounted on rear of engine and direct coupled.

(iii) Motors (Weight 2850 lbs. each)

Two independent motors are mounted transversely and supported from the final drive, which has a reduction ratio of 5.3.

(iv) Exciters & Auxiliary Generator (350 lbs. each) (300 lbs.)

There are three exciters and one 4.8 kilowatt battery charging generator which supplies current for the various tank services. The exciters are associated respectively with the field circuits of the main generator and the two main motors.

Thus four units are installed on either side of the generator in pairs. Each pair is belt driven from a countershaft which is itself driven by a propellor shaft from the engine fan drive take off. Each unit mounts a fan which provides the air flow for engine and transmission cooling.

(v) Wiring.

All wiring is carried out with harness fitted with "Cannon" type multiple pin connectors for easy replacement in sections.

(b) Auxiliary Equipment.

This includes the following items:

Control units.
Instrument panel.
Braking contactor.
Resistors.
Tachometer Generator controlling vehicle speed.
Tachometer Generator controlling engine speed.

(c) Transmission Cooling.

Cooling air is driven into the outer ends of the main motors and passing over the armatures, brush gear and parking brakes enters the rear end of the main generator. It passes over the brush gear and armature of the generator, and is discharged radially into the engine compartment. The transmission cooling air is taken from the fans before passing through the engine radiators, but subsequently passes through them and is discharged through grilles past the resistors. For transmission cooling 2,000 cu. ft. of air per minute is used.

(d) Servicing.

The brush gear of both generator and motors can be changed without removing the unit from the tank. It is reasonably accessible.

The engine and main generator can be lifted out as a unit.

The main motors cannot be removed without dismantling the rear armour casting. This casting is divided thus permitting the removal of an assembly weighing 4,900 lbs. and consisting of one motor, one final drive and one half of the rear armour casting.

Special "check panels" will be provided for locating faulty units. These will be of two types, one about the size of a portable typewriter, which will be carried on each tank, and the other a larger and more elaborate piece of equipment. It is expected that field maintenance will be accomplished largely by the replacement of faulty or damaged units.

(e) Miscellaneous.

No trouble has been experienced with screening, and it is claimed that more radio interference arises from the tracks than from the electrical equipment.

The electrical equipment is reported to be unaffected by the use of the armament but so far the machine has not been subjected to artillery attack.

(f) Test Results.

Tests to date on two prototype machines have given very encouraging results. On one machine at Fort Knox 4,000 miles have been completed on a 24 hour schedule, of which 8 hours were spent on the road and 16 hours on cross country (test weight 68,000 lbs.). General Electric have run the other at Erie for 2,700 miles mainly cross country. This machine has since completed a further 1,200 miles at Camp Seeley. The small amount of trouble encountered was not of a nature to occasion serious concern.

(g) Driving.

Members of the Mission drove a prototype on open cross country at the Chrysler Tank Arsenal Proving Ground. They also witnessed a comparative trial between this machine and an M4 with Ford engines in both machines. The T.23 showed up to great advantage on the sharp turns, but there were few gradients in the circuit to demonstrate relative hill climbing ability. In spite of its additional weight the T.23 completed the course in approximately 8 minutes as against 10 minutes for the M4.

The high reverse speed obtainable with the electric transmission was demonstrated very effectively.

The driver's controls are as follows:

(i) Two small levers with finger grips.

(ii) Accelerator pedal.

(iii) Parking brake.

Driving procedure is as follows:

(i) Start Engine.
Engine may be run up without moving machine.

(ii) Squeeze Finger Grips. (One or both)
With foot off accelerator, machine creeps forward.
When accelerator is pressed, machine gains speed as desired up to maximum.

(iii) Pull both levers back.
This introduces powerful electrical regenerative braking, increasing in intensity as the accelerator is depressed, and ultimately high speed reverse.

(iv) Pull one lever.
This puts machine into a turn. Power is very well maintained. The control is progressive.

(v) Release levers and finger grips.
Machine will coast.

(h) Driving Impressions.

Members of the Mission had no opportunity to check the nicety of the steering on narrow roads or in confined spaces. There is little doubt, however, with regard to the extreme controlability of the machine and the ease with which a novice can learn to handle it at least in open country. Some criticism was offered against the necessity of maintaining pressure on the finger grips for long periods and against the fact that if both hands are removed from the controls to hold on over a severe bump, the drive is temporarily lost. The necessary finger pressure is, however, very light.

The performance is excellent. Maximum tractive effort is stated to be 85%. The machine must not, of course, be held stalled on full throttle for appreciable periods or excessive electrical heating will occur since the full power output of the engine will be dissipated in the electrical circuits.

(i) Installation.

The installation is exceedingly compact. When the various units are seen spread out on the floor, it is difficult to believe that they can be accommodated in the limited machinery space available.

(j) U.S. Opinion.

The Ordnance Department in Washington, as represented by General Barnes, is exceedingly enthusiastic.

The Tank Automotive Centre, as represented by General Christmas, is rather non-committal, and views the weight of the equipment and the service problem with some concern. General Christmas also stated that the existing electrical equipment would handle 70,000 lbs., but would not handle the T.26 at 90,000 lbs.

The Chrysler Corporation, as represented by Mr. Keller, is well pleased with the progress made.

General Motors Corporation, as represented by Mr. McCuen, naturally prefers the hydraulic approach which they are themselves sponsoring.

Their chief points are:-

(i) Weight difference (about 3,000 lbs.)

(ii) Difficulty in educating army personnel to handle electrical equipment.

THE TORQMATIC TRANSMISSION (GENERAL MOTORS CORP.)

The Torqmatic Transmission consists of the following items all contained in a common case which is bolted up to the rear of the engine forming a complete unit:

(1) An input reduction gear (approx. 1.3 to 1) driving

(2) A torque converter

(3) An epicyclic gear set giving three forward speeds and reverse. Gear shifting is effected by a manually controlled hydraulic servo system operating band brakes and plate clutches.

(4) A cletrac steering unit bevel-driven from the epicyclic gear shaft.

The purpose of the reduction gear is to determine the speed of the torque converter in relation to that of the engine so that the desirable maximum speed for the converter is not exceeded on drive or over-run when the engine is used as a brake on long declines.

An important feature of this converter is the supply of oil under high pressure to the turbine casing. This permits the transmission of the high power necessary for this application without cavitation and so enables an extremely compact converter to be used.

The Model 900.T. as fitted to the T.70 Gun Motor Carriage (40,000 lb.) has the following characteristics:

	Epicyclic Gear Ratio	Speed M.P.H.	Torque Multiplication
Low Range	1 to 1	0 to 16	Max. 4.8 Min. 1.
Inter. Range	1 to 2.337	0 to 34	" 2.05 " .428
High Range	1 to 4.105	0 to 60	" 1.17 " .244
Reverse Range	1 to 1.330	0 to 22	" 3.45 " .720

The converter gives a stall torque multiplication of 4.8 to 1 at zero efficiency. The efficiencies at other ratios are as follows:

.250 ratio - 63%

.500 ratio - 78%

.600 ratio - 80%

.750 ratio - 78%

.870 ratio - 75%

It is imperative, therefore, to use the most suitable gear range, particularly when operating under full power, to avoid excessive overheating of the converter oil, and unnecessary fuel consumption. Cooling for the oil is allowed for at the rate of 25% of the engine horse-power. As a warning to the driver a red light indicating excessive oil temperature is under consideration.

The speed ranges quoted are as follows:

Low Range	0 - 16 M.P.H.
Intermediate Range	12 - 34 M.P.H.
High Range	30 - 60 M.P.H.
Reverse Range	0 - 22 M.P.H.

A unit combined with the Ford Engine is also being installed in the Medium Tanks T.25 (70,000 lb.) and T.26 (90,000 lb.).

Members of the Mission visited the plant of the Detroit Transmission Division of G.M.C. where the Torqmatic Transmissions units are being produced for T.70. At that date (November 30th, 1943) 500 sets had been produced.

Although the assembly shop is airconditioned and kept very free from dust, no difficulty in field servicing is expected by the makers, who said that the Hydramatic gear was serviced satisfactorily in North Africa.

DRIVING CHARACTERISTICS OF THE TRANSMISSION.

(1) The engine cannot be stalled; the converter will apply torque to a locked Transmission, even at light throttle openings.

Prolonged use of too high a ratio when extricating the vehicle from a ditch would result in the overheating of the converter oil and must be avoided.

(2) Owing to the lag characteristic of the torque converter, the sudden engagement of a gear clutch or brake does not produce a shock load even though the engine be at maximum speed and the throttle be opened rapidly on get-away. No initial get-away can therefore be quite as rapid as with the orthodox transmission given an expert driver.

(3) A gear can be engaged on an incline with the engine at tick-over without stalling, and the throttle subsequently opened up, when the vehicle will move off as soon as adequate tractive effort is developed.

(4) Gear range changes under power and on the move can be carried out without shock. An interval of no drive is avoided by the timing of the operating valves which provide progressive and overlapping disengagement and engagement of the brakes and clutches of the other.

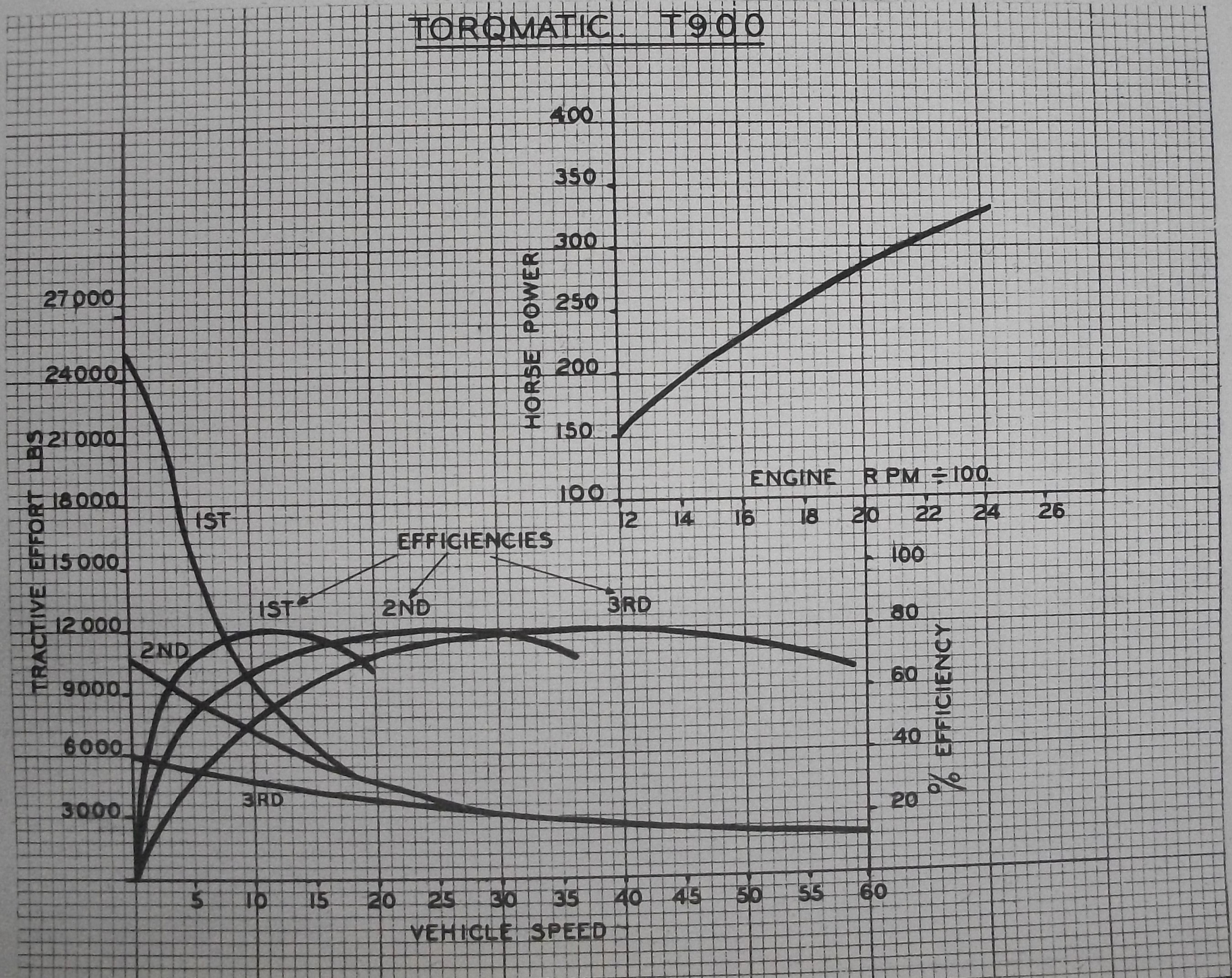
(5) A maximum speed in reverse of 22 M.P.H. is obtained on the T.70.

(6) Much has been said about the efficiency of the torque converter, which may normally range from 32% to 80%. Even so, it is stated that tests on a cross-country course show that the Torqmatic scores since the engine is operated more frequently under optimum conditions.

In the case of road work in the high ratio there is a case for the introduction of a solid drive as projected in the Spicer scheme.

(7) Owing to the low efficiency of the torque converter on over-run, the engine is protected from the danger of being driven at an excessive speed.

A T.70 vehicle was driven by members of the Mission. We were much impressed by the ease of handling and by the shockless nature of the change from one range to another. When comparing this transmission with the General Electric transmission it must not be forgotten that steering with the former is by the Cletrac principle and in consequence relatively crude.


TORQMATIC T900
HORSE POWER
400
350
300
250
200
150
100
ENGINE R PM ÷ 100.
12
14
16
18
20
22
24
26
TRACTIVE EFFORT LBS
27000
24000
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12000
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6000
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1ST
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EFFICIENCIES
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VEHICLE SPEED

HYDRAMATIC (GENERAL MOTORS CORP.)

The Hydramatic Transmission consists of a fluid coupling on the engine followed by a 3 speed and reverse epicyclic gear box automatically operated. The gear box is driven in such a manner that 60% of the engine torque is applied directly to the transmission and 40% through the fluid coupling, so reducing the duty on the latter.

This transmission is fitted to the M5A1 Light Tank which has a power weight ratio of 12 BHP per long ton, and to the T17E1 Armoured Car, having the same power weight ratio.

It is also used on the new Light Tank T.24 of which 1,000 have been ordered (production to commence in May).

The Twin Cadillac Engines are coupled by a 2 speed transfer box in which the speed change was originally operated by the Hydramatic principle.

With such relatively poor power/weight ratios in difficult country, the transfer box has a destructive tendency to hunt owing to the "mind changing" of the automatic mechanism, thereby throwing heavy duty on the epicyclic brake bands.

The control was given a wider overlap to overcome this feature, and was subsequently made manual.

Similar hunting must occur on the 3 speed boxes on the engines, but here, since the ratio steps are relatively small, the effect is not destructive.

SPICER TRANSMISSION (GENERAL MOTORS CORP.)

This transmission, which is in the development stage, is being sponsored by:

Yellow Truck and Coach Division of G.M.C.

Spicer Manufacturing Corp.

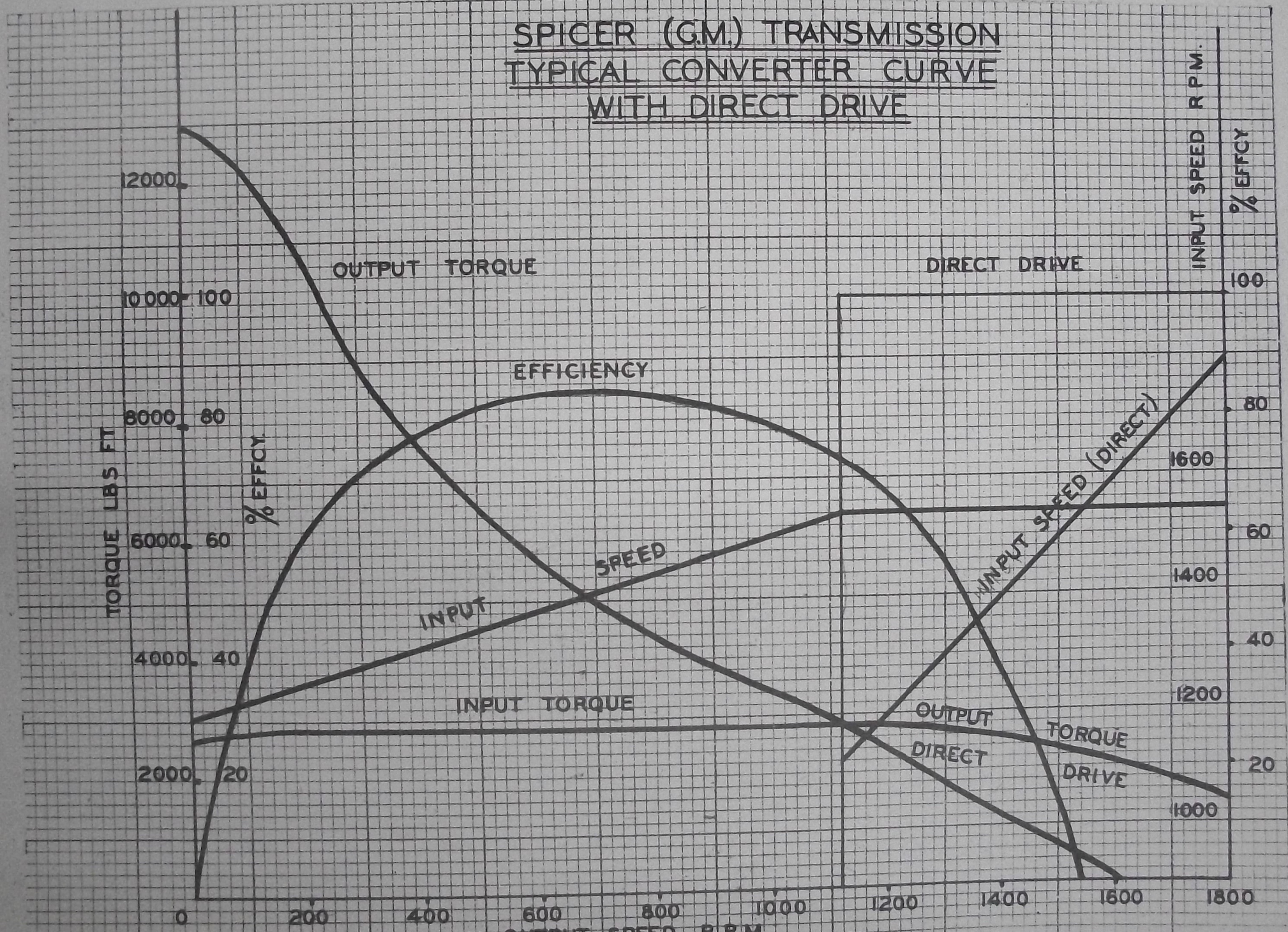
Twin Disc Clutch Corp.

As its background it has the "gearless" bus transmission which consisted of a torque converter having a 5 to 1 ratio with no subsequent change speed gear. A double clutch is placed between the engine and the converter, making it possible to engage either the converter or the central direct drive to the rear axle. The clutches are engaged automatically by a governor when the input torque equals the output torque. A graph of the characteristics of this gear is attached. This system is used on certain G.M.C. rear-engine buses.

A derivative of this gear is being developed for the Medium Tank (M4). It consists of the bus transmission, in this case, followed by a 3 speed and reverse synchromesh gear box. In one proposal the direct drive clutch is replaced by an air operated Salerni Coupling.

The main advantage of this transmission over the Torqmatic is that it provides a direct drive eliminating the converter at times when the latter would tend to become overheated.

SPICER (G.M.) TRANSMISSION
TYPICAL CONVERTER CURVE
WITH DIRECT DRIVE



Opinion in the Ordnance Dept. appears to be unanimous that for low power weight ratio vehicles the clutch and orthodox transmission must give place to an infinitely variable gear. The reasons stated are as follows:

1. The unreliability of the clutch in the hands of untrained drivers and the low percentage of good drivers available.

2. The operational importance of relieving the driver from the preoccupation of gear shifting.

3. The reduction of driving fatigue in heavy cross-country going. This is important to the U.S. who have to visualize operations in tropical climates.

4. The protection of the engine and transmission from heavy shock loads. Slogging of the engine at low speeds is eliminated.

5. Improved engine conditions, because even poor drivers can select the correct gear range.

   Petrol consumption tests claim to have demonstrated this on cross-country work.

6. Maintenance of continuous tractive effort in heavy going, at times when, with the orthodox transmission, gear changes would be unavoidable.

APPENDIX 2

SUSPENSION OF ARMOURED FIGHTING VEHICLES IN THE U.S.

With the improvement in design of the vertical volute spring a reasonable degree of reliability is now being experienced with the M.4. Suspension. The limit to the speed and weight of the vehicle is the bogie wheel tyre life. A ceiling appears to have been reached on the Chrysler M4A4, having the multibank engine. The vehicle weighs 71,900 lbs, and has a maximum speed of 23 M.P.H. Each unit carries a weight of approximately 13,000 lbs.

Since T.23 (Chrysler with Electric Transmission) has this Suspension, and cannot without considerable redesign use the torsion bar because the latter would foul the transmission, this vehicle is limited in the amount of armour which it can carry

In order to compete with the T.26 (G.M.C. and Torqmatic Transmission) the Chrysler Corp. have renewed their interest in the horizontal volute suspension which was being developed as a replacement for the vertical volute design of M.4. It has been so redesigned to accommodate a 23" wide centre guide lug track.

This suspension has the following advantages over that of M.4:-

1. The spring is used in pure compression and is neither bent nor displaced sideways.

2. The bogie wheels are retained at 20" diameter and the aggregate tyre width is increased from 9" to 13".

3. The 23" wide track can be used.

4. It is not likely to take long in reaching a development stage suitable for production.

5. It is a unit assembly which is easy to build and maintain in the field.

A feature of this design, vis-a-vis that of M.4., is that the inherent friction has been reduced. This has entailed the introduction of the horizontal flit-gun shock absorber.

It falls short of the torsion bar suspension of T.26 in the following features:-

1. The wheel movements are small and little different from those of M.4. (Single wheel - bump $2\frac{1}{2}$", rebound 4", bogie movement 10" bump).

2. Its carrying capacity is obtained by tyre width as opposed to diameter as on the torsion bar system. Road camber is causing the inner wheel to run much hotter than the outer.

Opinion in the Ordnance Dept. and in the B.S.M. is that the torsion bar design will win. It must be remembered that although this design is going into production on T.24 and T.70 the weights of which are 37,000 lbs. and

40,000 lbs respectively, the only experience gained so far on a Medium Tank is on the M4E4 running at 70,000 lbs weight and at a maximum speed of 29 M.P.H.

Certain members of the Mission made a special visit to General Motors Corp. to study the design and development of this suspension.

An earlier form of this suspension was tested on the M4E4 of which two pilot models were built. Members of the Mission drove one of these pilots at the Milford Proving Ground and were favourably impressed with the smooth and well controlled ride. This design incorporated a device for automatic track tension compensation on the rear idler only. As the result of the experience with these pilots it was decided to adopt torsion bar suspension of a very similar design on the low silhouette machines of which T.25 and T.26 are now under active development. The first vehicle of this type, T.49, had track tension compensation both on the front idler wheel and on the rear sprocket, vertical coil springs being used in the place of torsion bars.

A film of a 1/5 scale model tank was shown to the Mission to illustrate the advantages claimed for track tension compensation, which are:-

1. The reduction of the tendency to pitch. As the front wheel is forced towards the bump position, the tension in the inclined portion of the track is increased, and the resulting force on the front idler causes the upward movement of the bogie to be resisted, the idler being coupled to the front station by means of a linkage.

   The effect is that of an increase in spring load on the No.1. station.

2. The reduction of the tendency of the machine to dive when braking, or rear when accelerating.

3. The maintenance of an adequate tension in those portions of the track which otherwise become slack in certain circumstances.

The Mission were given an opportunity of studying the designs of the Torsion Bar Suspension as fitted to T.25.

The machine has six wheels per side. The front arm is 20" long and actuates the front idler to provide track compensation. As the result of experience, and in the interest of simplicity, track compensation is not provided for on the rear drive sprocket. The remaining arms are 16" long. With the exception of the rear station all of the arms trail and all are splayed outwards towards the road wheel hub.

The bump stop, which consists of a volute spring acts on an inward projection of the wheel stub. Although the splayed arm relieves the torsional stress in the arm until the bump stop is contacted, it does not reduce the maximum stress which is obtained when the full bump condition is reached.

The arm section of T.25 is rectangular, and at the pivot boss measures 4.500" x 3.500". An increased section is used on T.26.

Needle roller bearings are used on the pivot shaft which are spaced only $5\frac{1}{2}$" apart. The housing for these bearings, and for the anchorage of the torsion bar of the station on the opposite side consists of a B.P.casting bolted to the under side of the hull. The hull floor, which is inclined at the sides, is machined locally to receive these housings.

The torsion bars of T.25 are approximately 2" in diameter. The serrations have an included angle of 96° 88' and a total depth of .040". The base radius of the spline is .040". The bars themselves are ground before and after heat treatment, shot blasted, Parkerized and enamelled. Before installation they are wrapped in rubberized tape. This is done to protect them from corrosion since they are exposed throughout their length in the hull. The maximum stress is 140,000 P.S.I, the hardness called for being 460-485 Brinell.

For T.25, the static deflection at the bogie wheel is $4\frac{1}{2}$" to 5" and the total movement 13 to $12\frac{1}{2}$". On T.26 the torsion bar diameter will be increased and the initial deflection reduced.

On T.25, which the designers speak of as weighing 70,000 lbs, the tyre width per wheel is 6-1/8" nominal, which gives a loading per inch of width of 480 lbs. The tyre is bonded directly to the wheel which is made in work-hardening steel in order to prevent undue wear on the flange running against the track guide lug. Both T.25 and T.26 will have steel spud tracks with rubber bushed pins, the widths being 19" and 23" respectively. It is worthy of note that T.25, with an overall width of 124" over tracks will negotiate the Bailey Bridge. The T.26 in which this dimension increases to 134" is outside the prescribed limit.

An interesting feature of the design as inspected is the light section of the arm for a vehicle weighing 70,000 lbs. and having a reputed speed of 32 M.P.H. Although T.70 has a suspension of this type with track tension compensation on both the track idler and the sprocket, it is reported still to show a tendency to pitch and bottom on the front station as do Centaur and Cromwell. The volute spring of the bump stop has a rate increasing with compression, but the final stop is the casing. Shock absorbers are fitted to the two front and the two rear stations. Information has been received that on T.70, which is a high speed vehicle, difficulty is being experienced in making the shock absorbers stand up to the heavy duty imposed upon them. Consideration is being given to using a damper on No.3. station.

It seems fair to assume, in view of the above remarks, and in the light of experience on similar suspensions in the U.K. that the torsion bar suspension for T.25 and T.26 may take some while to develop to a stage where it can be put into production.

It is apparent, therefore, that the heavy armour with the 90 mm gun (T26) is dependent, amongst other things, on the success of the Torsion Bar Suspension.

It is just possible that the Chrysler Corp. may put up a project consisting of their horizontal Volute Suspension and the Electric Transmission with T.25 armour. They have been asked to produce a T.25 with such a drive and in view of the fact that the Torsion Bar Suspension is ruled out with the electric drive, the vehicle may take the form suggested.

There is a revival of interest in the T.1 Suspension in that the torqmatic pilot is being sent from Milford to Aberdeen to resume running.

APPENDIX 3.

TRACKS

The shortage of rubber has forced the U.S. to consider the use of less rubber in the construction of vehicle tracks.

On the existing M4 series of vehicles some tracks have steel treads with chevrons instead of the original rubber tread. The side guide lug with the twin pinned link using rubber bushings is retained universally. No indication was apparent of any further effort to dispense with the rubber tyre path of the track.

Whilst synthetic rubber is being used in the construction of this tyre path, no use is made of this material in the track pin bushes owing to the heavy duty imposed upon them.

It is interesting to note that on all new designs, such as T70, T23, T24, T25 and T26 an all steel centre guide lug track is being used, having a single rubber bushed pin. In the case of the narrower tracks, the sprocket drive is on the edges of the track, whilst on the 23" wide track the drive is taken through rectangular slots. In all cases the tyre path is free from interruptions.

Although the T24 will go, and T70 has gone, into production with these tracks, there is evidence to show that they are not considered by the U.S. Ordnance as being entirely satisfactory. The use of a single pin construction has increased the duty of the rubber bushes which on the M4 tracks were taxed almost to the limit. It is contended that track tension compensation helps to reduce the amount of work on the pin bushes by reducing the tendency of the slack portion of the track to wave. Guide rollers are used universally to control the top run.

The links are cast and the pin holes are broached. The pitches of the tracks are generally larger than those to be found in use in the U.K. Data on the various tracks is given below.

Vehicle.	Track Width.	Pitch.
T23.E3.	19 ins.	5-19/32 ins.
T24	16 ins.	5-1/2 ins.
T25	23 ins.	6 ins.
T25.EI	19 ins.	5-1/2 ins.
T26.EI	24 ins.	6 ins.
T70	14 ins.	5-3/32 ins.

There is no evidence of any work having been done in U.S. on the use of the British type of dry-pin track.

In Canada, Montreal Loco have developed and are using an all steel dry-pin track for their gun motor carriage, the Sexton. It is a Sherman hull, M4A1, on which is mounted a 25 pdr. gun, the vehicle

weight being some 10,000 lbs less than that of the tank. The shoe is cast in austenitic manganese steel, is 15-1/2" wide, and has a pitch of 4.6". The pins are 13/16" nominal diameter, and are in homogeneous steel to specification, S.A.E. 9255. According to drawing, the maximum permissible diametral slack in the pin on a new track does not exceed .0185". It is worthy of note that sample tracks which were examined showed excellent casting technique. The links were free from blow-holes and cold-shuts. The holes in adjacent lugs were accurately in line, and the pin holes at each end of the links were remarkably parallel.

This track was tested on a Sherman Tank (M4) and had a life of 2,500 miles. The vehicle weighed 68,000 lbs. Satisfactory tests were carried out by the U.S. Ordnance on this track but no further action was taken.

It is recommended that four vehicle sets of these tracks and appropriate sprockets be despatched to U.K. for trial at F.V.P.E.

Montreal Loco are delivering Sextons fitted with the dry-pin track, but it is understood that vehicles so equipped will be used only for training purposes. In the interest of standardisation the rubber block track will be used in the field.

Montreal Loco have made and tested some sprockets for Sexton from steel, centrifugally cast. It was stated that these sprockets showed a much improved life over those cut from plate. The only machining carried out on the sprocket was on the bore and face of the attachment. They would be submitted for acceptance but for the fact that the foundry at Montreal is already very over-loaded.

A similar development has been carried out by Ford Windsor, on the sprocket for the carrier. These sprockets are centrifugally cast in steel, the only machining being the bore and counter bore for the attachment. Such sprockets are in production.

APPENDIX 4.

THE RUBBER SITUATION.

Both in Canada and the U.S. the Mission was made conscious of the most vigorous efforts to conserve natural rubber.

Early in our travels, when visiting the Montreal Loco Works, we saw Sextons - the 25 pdr. S.P. on the M4 chassis - being built with a Manganese steel dry pin track. We were told that, although some machines with rubber tracks were still going down the line, future production would use 100% steel.

The disastrous effect on the M4 tank bogie tyres of just such a change will be remembered but it should be noted that the Sexton, being 10,000 lbs. lighter than the M4 tank, the cases are not truly parallel. In the interests of interchangeability machines equipped with all steel tracks will be retained for training purposes.

At the Ottawa Proving Ground, we learned of an experiment on M4 to substitute complete steel bogies running on steel tracks for the normal rubber tyred units. The results had been encouraging, no ill effects being reported on hub bearings and the noise not being considered excessive. A life of 300 miles was being obtained on the front wheels and 600 to 900 miles on the remainder. The wheels were being modified in the light of these experiments, and further tests were to be run.

In contrast to these attempts to eliminate natural or synthetic rubber entirely, U.S. Ordnance, through the Tank Automotive Centre at Detroit, are making every effort to cut down their natural rubber demands by the use of synthetic. Apparently very little success has been met with mixtures of natural rubber and synthetic. Such mixtures are not used in any applications except in certain components of some pneumatic tyres. The reason for this is given in simple terms as follows:-

Synthetic rubber generates more heat than natural rubber but is better able to resist high temperatures. In mixtures, the synthetic content causes temperatures high enough to damage the natural rubber content.

We were told by members of the T.A.C. that the total bogie, track and pneumatic tyre usage for the U.S. armed forces wheeled and tracked vehicles now comprises 70% synthetic. In 1944 they are scheduled to raise this figure to 80%; representing the vast total of 165,000 long tons.

The rubber bands of half-tracked vehicles are made with natural rubber treads in contact with the road and synthetic rubber for the tyre path. Of the total volume, 30% in synthetic. These bands are good for about 3,000 miles. Synthetic is used exclusively for the bogie tyres on these machines, and they give a life of from 5,000 to 10,000 miles, depending on the service conditions.

Both tracks and bogie tyres on the current light tanks are of synthetic rubber exclusively and these are good for from 2,300 to 3,000 miles.

It is to be noted, however, that no attempt has been made to use anything but natural rubber in the bushings of U.S. tracks, nor is any such attempt likely to meet with any early success.

On medium tanks, 40% of all production use synthetic rubber, but these are all of the smooth tread type. The remaining 60%, of which a proportion is of the chevron tread type, uses natural rubber. The synthetic tracks give a life about 75% of that obtained with natural rubber. With regard to tyres for medium tanks, 25% of the production uses synthetic rubber.

It is interesting to note that the bogie tyres and tracks on all new type suspensions were designed specifically for the use of synthetic.

On the wheeled vehicle side over a million synthetic tyres have already been produced for the forces and in 1944 all small vehicles are scheduled to use synthetic. Medium tyres, as used on the 3/4, $1\frac{1}{2}$, $2\frac{1}{2}$, 4 and 6 ton vehicles will be constructed of about 90% synthetic. Larger sizes will use perhaps 70% synthetic at the most.

The foregoing figures and the high standard of results obtained represent a tremendous amount of development work and reflect high praise upon the organisational ability of U.S. Ordnance and the ability of the Industry.

In view of the enthusiasm for synthetic, however, it is well to remember that the changeover from natural rubber has been brought about by absolute necessity rather than by the belief that an equivalent product would be obtained, at least for some time to come. The general belief with regard to wheeled vehicle tyres is that with reduced speeds and extra care and attention, synthetic tyres will give 75 to 80% of the life obtainable on natural rubber.

Interesting comment on the situation is provided by the action of the U.S. rubber industry which is at the present time running full page announcements in the leading newspapers warning automobile and truck drivers of the need for care and moderate speeds with synthetics, the reduction in life mileage, and the comparatively primitive state of the art.

APPENDIX 5.

FORD TANK ENGINE.

In the opinion of the Mission it may now be said that the 8 cylinder Ford Tank Engine has emerged from the development troubles associated with any new engine project, and is probably already the most reliable engine available to the U.S. Armoured forces.

As is well known, the engine is produced in a number of types to suit different machines, and in order to avoid confusion it may be well to include at this stage brief definitions.

GAA ... is the standard 8 cylinder engine as fitted to the M4A3. It was designed to replace a radial engine and has vertical carburettors and a deep wet sump.

GAY ... is fitted in the Centaur Tanks shipped to England and is also supplied against the British order for 20 engines. It has horizontal carburettors and a shallow wet sump - crankshaft centre line to bottom of sump 10½" - in order to fit into a low silhouette machine, and has a Meteor type fan drive.

GAZ ... is also a low silhouette type engine but is used only in T14 and is therefore of little interest at the moment.

GAF ... has horizontal carburettors but retains a deep sump and is used with the torqmatic transmission on T25 and T26.

GAN ... is similar in height to GAF but is designed for use with the electric transmission on T23.

Thus GAA, GAZ, GAF and GAN, fulfil a U.S. requirement, whilst GAY is at the moment the only anglicised version.

We were much impressed by the strip of one of the U.S. type engines when we visited the Lincoln plant on October 27th. This engine, despite the well known but much criticised Ford floating big end bush was in excellent condition after 400 hours running, during which time the tank into which it was fitted completed 5,095 miles.

Two items still subject to criticism on the U.S. type engines are:-

(1) The split floating big end bush, which as shown by the above strip can be perfectly satisfactory, but is considered too temperamental for normal production purposes, and

(2) The diagonal bolting for retaining the main bearing caps. With the type of location employed

this scheme makes it possible to pull the bearing out of line on assembly.

Both of these items have been changed on the British version GAY which employs fixed big end bearings made by Cleveland Graphite Bronze and vertical bolting for the main bearing caps.

These features will shortly be in production on the U.S. versions of this engine, and it is felt that this will set the seal of general reliability upon the product as a whole.

Owing to the interest now being shown in tanks weighing 40 long tons and over there is a revival of enthusiasm in the 12 cylinder version of the GAY engine. As will be remembered, this engine, known as the GAB, was originally built against a British requirement, but the three units completed were never released by the U.S. authorities. In the light of experience since gained with the 8 cylinder engines, further development is now in progress and an order for three pilots of an engine to be known as the GAC has been placed.

APPENDIX 6.

MINE DISPOSAL.

A great deal of urgent, if belated, attention is being given to the problem of mine disposal both in the U.S. and in Canada.

A most interesting and realistic approach has been made in Canada to the problem of gathering ideas from all available sources. The authorities in Ottawa summoned a conference of representatives from all Engineering and Scientific Societies. It was decided to prepare booklets describing the nature of the problem and also the present state of the art. Twenty-three thousand of these were circulated and fourteen competent lecturers were assembled for a two-day course. Two films were prepared illustrating present mine detection and disposal practice. The lecturers dispersed throughout the country and on a certain night delivered a prepared lecture and exhibited the films in the largest hall available in each district. In every case these lectures were fully attended and enormous interest was aroused. Already about 4,000 replies have been submitted to the authorities and the engineering societies are expected to offer their considered suggestions shortly.

The replies are examined and dealt with at local centres and only the most promising of them reach Ottawa, where trials are initiated. It may be of interest to mention a few of these as below:-

1. DI-ELECTRIC DETECTOR

   Prof. Gilchrist of Toronto University is developing a detector making use of the di-electric influence of buried mines whether metallic or non-metallic.

2. SMOKE DETECTOR.

   The ground in front of the vehicle is to be probed by steel nozzles through which air and smoke are forced under a small pressure. The smoke for this purpose is generated by injecting oil into the exhaust manifold of the main engine. The presence of mines is revealed by the fact that the soil above them is in a porous condition if they have been laid at all recently. The smoke emerges from the ground wherever a mine has been buried and the ground disturbed.

3. DETECTION BY INFRA-RED PHOTOGRAPHY.

   It is suggested that photographs taken from the air through an infra-red filter will disclose the position of individual mines in a mine field. It is proposed that accurate maps will then be prepared from the photographs, from which a route can be selected and cleared.

4. FISHERMAN'S JIGGER

The inspiration for this device comes from the North where the following method of fishing under the ice is practiced. Through a hole a mechanism is pushed under the ice and inched along by tugging on a line carrying with it a bated hook. An adaptation of this is to be tried for inching forward explosive charges for mine-field demolition.

5. BEARINGLESS ROLLER

A large roller made of armour plate and in the form of a rather thin-walled hollow cylinder is pushed ahead of the machine by means of a rod passing through it which is supported on out-riggers fixed to the hull. When the roller explodes a mine it flies around the rod, hitting the ground in front so absorbing the energy of the explosion, it is hoped without damage. It seems likely that the roller would have to be made in sections to conform to the contour of the ground.

6. SWISS ROLL

It is proposed to use large rollers made from spring steel in the form of wide clock springs. The thought is that the springy nature of these rollers will save them from major damage and that they will lose only small fragments from the outer coil.

7. SANDBAG FLINGER

A proposal has been made to explode mines by hurling heavy sandbags. Preliminary trials with 62 lb. bags dropped from 14 ft. are said to have failed to detonate mines. The proposal includes the suggestion to carry only unfilled bags on the machine and to charge these automatically with adjacent soil as the machine goes along.

8. COUNTERPANE

It is claimed that by spreading an ordinary sheet over a Cortex Net the downward effect of the blast is greatly accentuated.

In order to discover the extent and direction of mine blast, Dr. Rose of the National Research Council is making special apparatus.

In the U.S. progress is being made with the flail-type of mine destroyer applied to the M4 Tank. The flail takes its power from the main engine. The designs were not sufficiently far advanced to enable any detail information to be gathered.

We were shown a recent G.M. Development which has not yet been tried. The idea is to remove the tracks and suspension from a standard M4 Tank and to mount it on two immense wheels at the front end and on a trailing roller at the rear. A large additional gear reduction is provided in

the front wheels and steering is effected by means of the normal Cletr system. The front wheels are 8 ft. in diameter and 40 inches wide. The rear roller is 6 ft. in diameter and overlaps the imprints made by the front wheels.

The first wheels are being made up from welded armour plate using a very open grid-like tread through which the blast can pass. These wheels will weigh about 17,000 lbs. a-piece. It should be noted that the belly of the tank is raised well off the ground. Also, the tank carries its normal fighting equipment. This is considered to be a short term development, the minimum number of special components being involved.

APPENDIX 7

LIST OF DOCUMENTS AND IMPORTANT DRAWINGS OBTAINED BY THE MISSION BUT NOT INCLUDED WITH THE REPORT

1. U.S. War Department Manual on T16 Universal Carrier.
2. Scheme drawing of Mr. Olley's proposed independent suspension for T16 Carrier.
3. Drawings of T25 Torsion Bar Suspension.
4. Churchill and Carrier Springs redrawn by Mr. Olley to incorporate best U.S. manufacturing procedure.
5. SAE Manual on design and application of helical and spiral springs for Ordnance.
6. Drawings of $15\frac{1}{2}$" dry-pin steel track link and pin used on the Sexton by Montreal Locomotive.
7. Brochures prepared by Canadian Department of National Defence on the Tracked Jeep.
8. Brochure prepared by the Studebaker Corporation on the U.S. T24 Light Cargo Carrier.
9. Brochure on general characteristics of MX combat vehicles. (T24 and derivatives).
10. Ordnance Department (T.A.C.) Characteristic Sheets for experimental vehicles.
11. U.S. Ordnance Manual on the form taken by automotive tests at Aberdeen Proving Ground.
12. Folder on Desert Training Centre at Camp Young, California.
13. Copies of the General Mechanical Aptitude Tests to which all entrants are submitted at the Armoured School, Fort Knox.
14. Reports and drawings prepared at Fort Knox on "Visual requirements and on sighting telescopes and periscopes for tanks".
15. Layout drawing of the Hydramatic Transmission prepared by the Detroit Transmissions Division of G.M.C.
16. Brochure on 900T Torqmatic Transmission.
17. Brochure on General Electric Transmission.

APPENDIX 8

LIST OF PLACES VISITED

U.S. War Department, Pentagon Building, Washington, D.C.

U.S. Ordnance Proving Ground at Aberdeen, Maryland.

In Canada:-

Montreal Locomotive Works

Canadian Department of National Defence, Ottawa

D.N.D. Proving Ground, Ottawa

The Dominion Bridge Co.Ltd., Montreal

In the Detroit Area:-

U.S. Ordnance, Tank Automotive Centre

Chrysler Tank Arsenal

Chrysler Proving Ground, at Utica

Chrysler Engineering Laboratories

Cadillac Division of G.M.C.

General Motors Proving Ground, at Milford

Tank Section of the Fisher Body Division of G.M.C.

The Lincoln Tank Engine Plant of the Ford Motor Co.

Ford River Rouge Plant

Ford Motor Company of Canada at Windsor, Ontario

Ford Motor Company, Somerville, Boston, Mass.

The Detroit Transmission Division of G.M.C.

Briggs Manufacturing Co.

At Fort Knox, Kentucky:-

The Armoured Board

The Training Centre

The Armoured School

The Medical Research Board

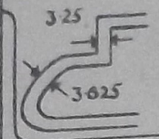
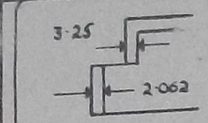
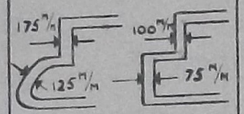
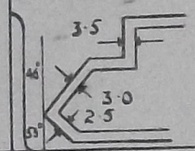
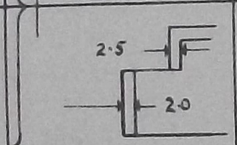
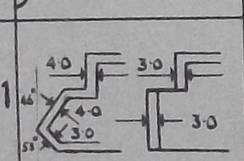
At Camp Young, California:-

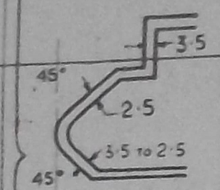
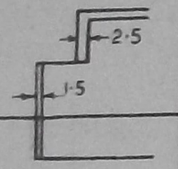
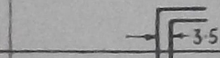
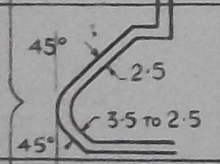
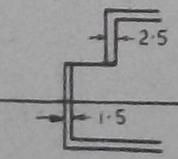
The Desert Training Centre

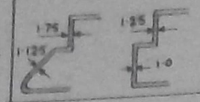
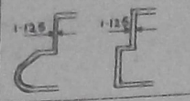
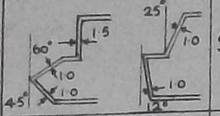
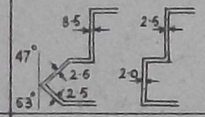
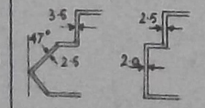
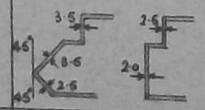
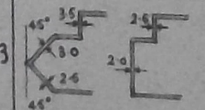
The Desert Warfare Board

At Philadelphia:-

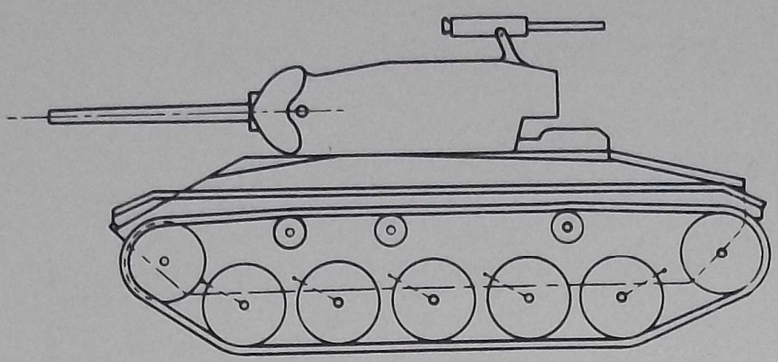
The Frankford Arsenal

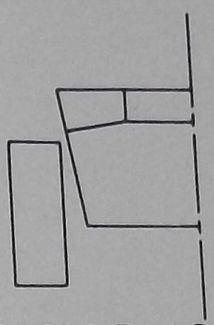
VEHICLE	ARMOUR	WEIGHT LB.	WEAPONS	MAIN ROUNDS CARRIED	ELEVATION AND DEPRESSION	PARENT	ENGINE	TRANSMISSION	SUSPENSION	TRACK	GROUND PRESSURE LB. SQ. IN.	MAX. SPEED M.P.H.	PILOT MILEAGE	REMARKS
M.6 (T1)		126,500	3 INS. A.A. GUN			BALDWIN LOCO.	WRIGHT G. 200 800 H.P.	TORQUE CONVERTER & MECH. GEARBOX	HORIZONTAL TWIN WHEEL VOLUTE SPRING	RUBBER BLOCK 25 3/4" WIDE		25		20 BEING PRODUCED
M.6 (T1)			3 INS. A.A. GUN			BALDWIN LOCO.	WRIGHT G. 200 800 H.P.	GENERAL ELECTRIC	HORIZONTAL TWIN WHEEL VOLUTE SPRING	RUBBER BLOCK 25 3/4" WIDE				20 BEING PRODUCED
T.14		95,000	75 m/m - M.3 GUN ·300 CO-AXIAL M.G ·300 BOW GUN				FORD G·A·N 515 H.P.	MECHANICAL AND CLETRAC	HORIZONTAL TWIN WHEEL VOLUTE SPRING (M6. TYPE)	RUBBER BLOCK 25 3/4 (M6. TYPE)	12·3	22	2 PILOTS	THIS WAS A U.K. REQUIREMENT
T.25		77,000	90 m/m - T.7 GUN ·300 CO-AXIAL M.G ·300 BOW GUN	48 RDS.	+ 25° - 10°	CHRYSLER ?	FORD G·A·F 470 H.P.	GENERAL ELECTRIC	HORIZONTAL VOLUTE WHEELS 20X6·5"	STEEL SPUD RUBBER BUSHED 23" WIDE 6" PITCH	11·4	30		PILOT INSTRUCTED
T25 E1		76,600	90 m/m - T.7 GUN ·300 CO-AXIAL M.G ·300 BOW GUN	42 RDS.	+ 25° - 10°	FISHER TANK DIV'N G.M.C.	FORD G·A·F 470 H.P.	TORQMATIC	TORSION BAR WHEELS 26" × 4 11/32"	STEEL SPUD RUBBER BUSHED 19" WIDE 6" PITCH	13·9	30		WOODEN MOCK-UP 40 MACHINES ORDERED PILOT DELIVERY DEC. 1943
T26 E1		85,700	90 m/m - T.7 GUN ·300 CO-AXIAL M.G ·300 BOW GUN	42 RDS.	+ 25° - 10°	FISHER TANK DIV'N G.M.C.	FORD G.A.F 470 H.P.	TORQMATIC	TORSION BAR WHEELS 26" × 6 1/32"	STEEL SPUD RUBBER BUSHED 24" WIDE 6" PITCH	12·4	25		WOODEN MOCK-UP 10 MACHINES ORDERED PILOT DELIVERY DEC. 1943.

		LB.														
M4	WELDED HULL		75 M/M				WRIGHT									
M4.A1		67,300				LIMA LOCO	WRIGHT R.975-C1 365 H.P.					24			
M4.A2		65,476	75 M/M WITH CO-AXIAL MACHINE GUN AND BOW GUN.			FISHER TANK DIV'N G.M.C.	G.M. DIESEL MODEL 6046 SERIES 71 375 HP	MECHANICAL & CLETRAC	VERTICAL VOLUTE	RUBBER BLOCK 16½" WIDE 6" PITCH		29			
M4.A3		68,400				FORD MOTOR CO.	FORD G.AA.					28			
M4.A4		71,900				CHRYSLER TANK ARSENAL	CHRYSLER A.57 445 H.P.					23			
M4			76 M/M WITH CO-AXIAL M.G. ·300 BOW GUN ALTERNATIVE 105 M/M HOW.			CHRYSLER	WRIGHT R.975-C1 340 H.P.								
M4.A1		69,810	76 M/M WITH CO-AXIAL M.G. ·300 BOW GUN	71 RDS.	+ 25° - 10°	PRESSED STEEL	WRIGHT R.975-C1	MECHANICAL & CLETRAC	VERTICAL VOLUTE	RUBBER BLOCK 16½" WIDE 6" PITCH	14·5	24		KNOWN AS M4.E6	
M4.A2			76 M/M WITH CO-AXIAL M.G. ·300 BOW GUN			FISHER TANK DIV'N G.M.C.	G.M DIESELS								
M4.A3			76 M/M WITH CO-AXIAL M.G ·300 BOW GUN ALTERNATIVE 105 M/M HOW.			CHRYSLER & FISHER	FORD G.AA.								
M4.A6	AS M4					CHRYSLER TANK	CATERPILLAR AIR-COOLED	MECHANICAL &	VERTICAL	RUBBER BLOCK			13 PILOTS	U.S. ORDER FOR 775	

VEHICLE	ARMOUR	WEIGHT LB			DEPRESSION						LB. SQ. IN	M.P.H.		
M3. A3.		32,946	37 M/M			G.M.C	CONTINENTAL W.670-9A 250 H.P	5 SPEED SYNCHROMESH & CLETRAC	VERTICAL VOLUTE SPRINGS	RUBBER OR STEEL 11 5/8 INS WIDE	11·3	36		REPLACED BY M5. A1.
M5. A1		32,340	37 M/M			CADILLAC MTR. DIV'N G.M.C.	CADILLAC SERIES 42. 220 H.P	HYDRAMATIC	VERTICAL VOLUTE SPRINGS			40		REPLACES M3. A3 IS IN PRODUCTION
T.9E1	TURRET 1" FRONTAL BASIS 1" SIDE HULL ·75" FRONTAL BASIS	15,800	37 M/M WITH ·300 COAX	50 RDS		MARMON HERINGTON	LYCOMING FLAT-SIX AIR-COOLED	4 SPEED SYNCHROMESH & CLETRAC		STEEL WITH SIDE GUIDES 11¼" INS WIDE	7 APPROX	40	TWO IN ENGLAND	AIR-BORNE TANK PRODUCTION HELD UP DUE TO DEFECTS.
T. 24		38,000	75 M/M & ·300 BOW GUN.	48 RDS	+15° −10°	CADILLAC G.M.C.	TWIN CADILLAC SERIES 42 242 H.P.	HYDRAMATIC	TORSION BAR WHEELS 24"×4½"	STEEL SPUD CENTRE GUIDE RUBBER BUSH 16 IN WIDE 5½ PITCH	10·6	35	TWO PILOTS	PRODUCTION IN MAY 1944
T. 24. E.1.	AS T. 24	38,000	75 M/M & ·300 BOW GUN	48 RDS	+15° −10°	CADILLAC G.M.C	WRIGHT 975	SPICER TRANSMISSION	TORSION BAR WHEELS 24"×4½"	STEEL SPUD CENTRE GUIDE RUBBER BUSH 16 INS WIDE	10·6	35	NO PILOT.	
MEDIUM TANKS (EXPERIMENTAL)														
T. 20			76 M/M & CO-AXIAL M.G ·300 BOW GUN.	68 RDS	+25° −10°	G.M.C	FORD G.A.N 515	TORQMATIC CONVERTER 3030 B.	HORIZONTAL VOLUTE WHEELS 20"×9"	RUBBER BLOCK 16 9/16" WIDE 6 INS PITCH	13·6	35		PREDECESSORS
T.20.E3	AS T.20						FORD G.A.N 515	TORQMATIC	TORSION BAR					OF T23 & NOW MORE OR LESS ABANDONED
T.22.E1		69,300	AUTO 75 M/M GUN & ·300 BOW GUN	100 RDS	+15° −10°		FORD G.A.N 515	MECHANICAL & CLETRAC	CHRYSLER HORZ. VOLUTE	RUBBER BLOCK 16 9/16 INS WIDE 6 INS PITCH	14·3	25	TWO PILOTS	
T. 23		72,500	76 M/M & CO-AXIAL M.G ·300 BOW GUN	68 RDS	+25° −10°		FORD G.A.N	GENERAL ELECTRIC	VERTICAL VOLUTE	RUBBER BLOCK 16 9/16" WIDE 6 INS PITCH	15·0	35	TWO PILOTS 4·041 3·900	U.S ORDER OF 250 35 PER MONTH CAN MOUNT THE 90 M/M GUN
T.23.E3		73,500	76 M/M & CO-AXIAL M.G ·300 BOW GUN	68 RDS	+25° −10°		FORD G.A.N	GENERAL ELECTRIC	TORSION BAR WHEELS	STEEL WITH RUBBER BUSHES 19 INS WIDE 5 25/32 INS PITCH	12·8	35		
M4. E4	AS M 4.	70,000	75 M/M WITH CO-AXIAL M.G ·300 BOW GUN			FISHER TANK DIV'N	G.M. DIESEL 420 H.P	MECHANICAL & CLETRAC	TORSION BAR	STEEL SPUD RUBBER BUSH 23" WIDE	13·9	29		EARLY PILOT FOR TESTING TORSION BAR

LIGHT TANK T24

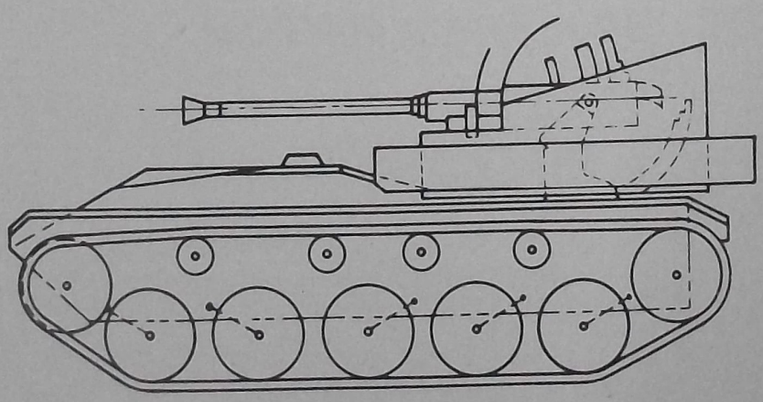


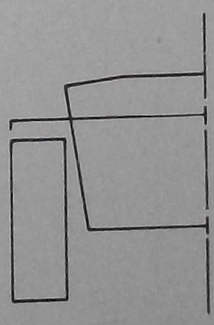


75 M.M. GUN
WEIGHT-18 1/2 TONS

BASIC ARMOR-1

MOTOR CARRIAGE T65E1

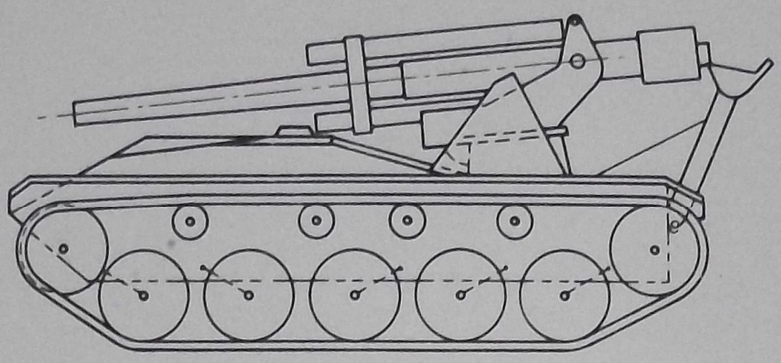


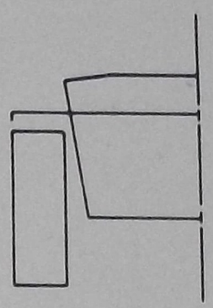


TWIN 40 M.M. A.A. GUNS
WEIGHT-19 TONS

BASIC ARMOR 1/2

MOTOR CARRIAGE T16E1

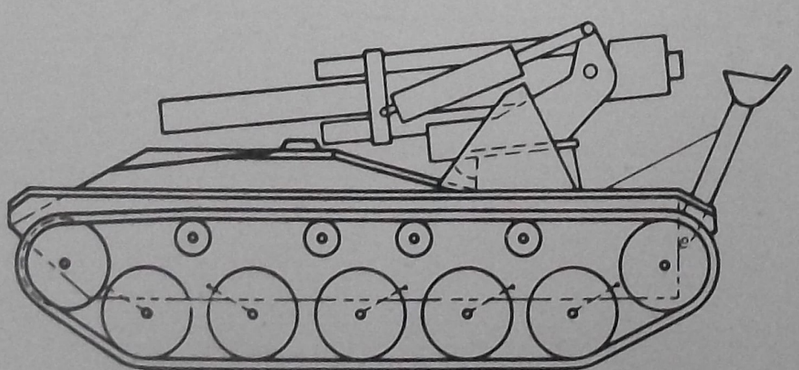


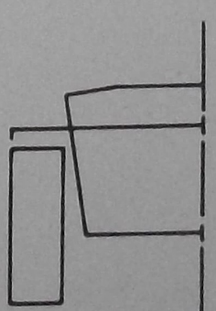


4.5 INCH GUN
WEIGHT-19 1/4 TONS

BASIC ARMOR- 1/2

MOTOR CARRIAGE T64E1

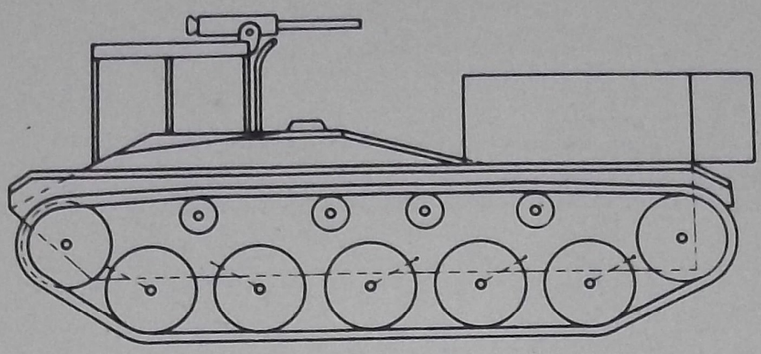


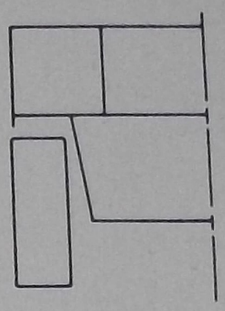


155 M.M. HOWITZER
WEIGHT-19 1/2 TONS

BASIC ARMOR- 1/2

CARGO CARRIER T22E1 & T23E1

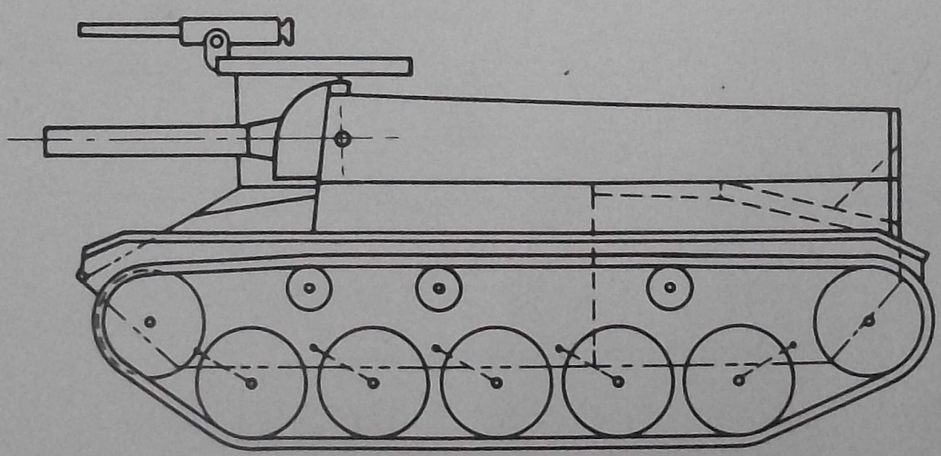


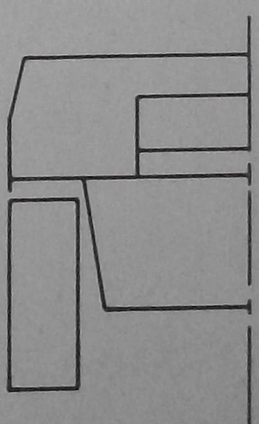


WEIGHT- T22 - 19 TONS
T23 - 18¼ TONS

BASIC ARMOR- ½

MOTOR CARRIAGE T76

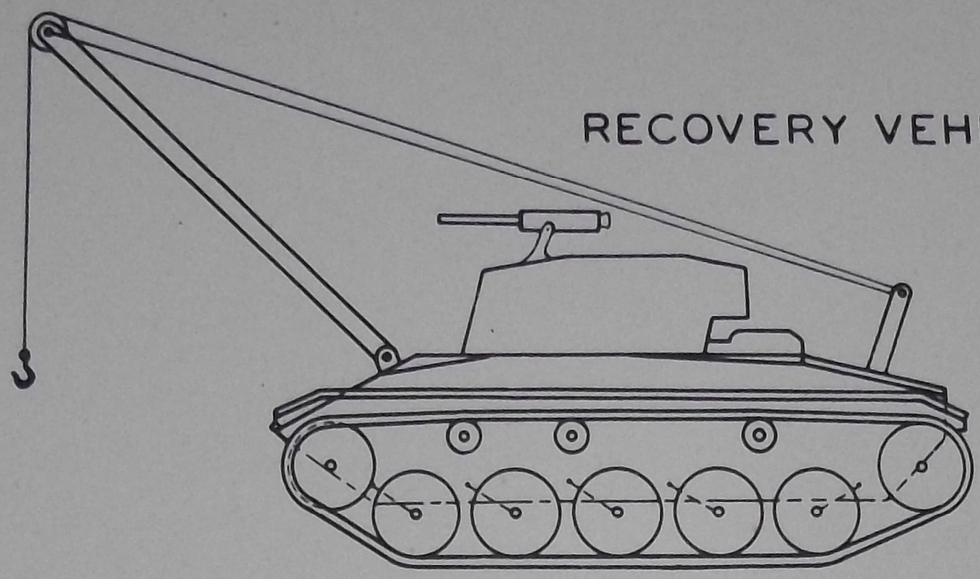


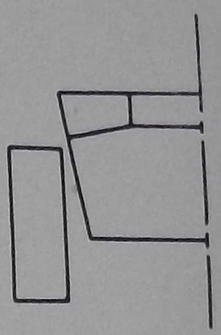


105 M.M. HOWITZER
WEIGHT - 19 TONS

BASIC ARMOR- ½

RECOVERY VEHICLE

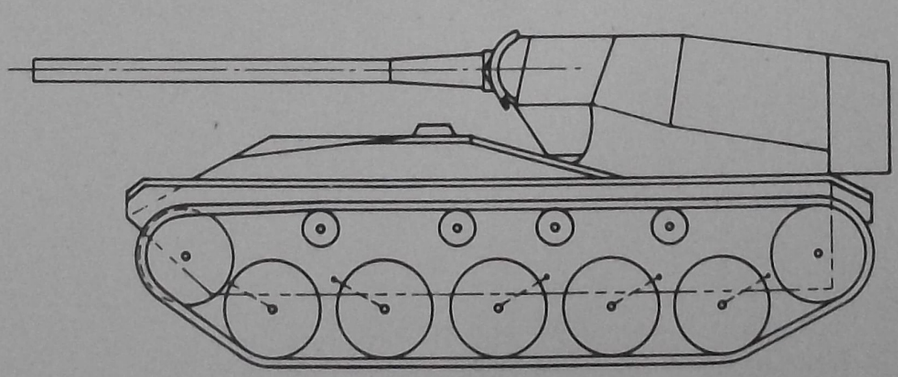


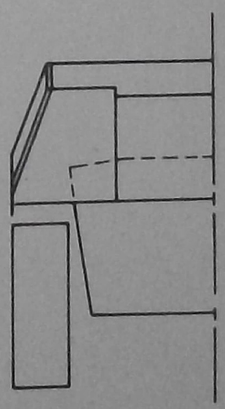


WEIGHT-19 TONS

BASIC ARMOR-1

90 M.M. MOTOR CARRIAGE





90 M.M. GUN

WEIGHT-18 3/4 TONS

BASIC ARMOR - 1/2